GOES-R Products and Data Dissemination Options

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Mathew M. Gunshor, Jun Li
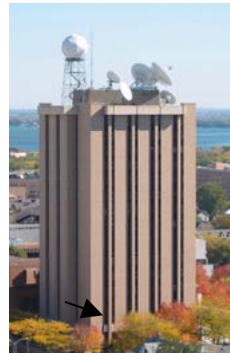
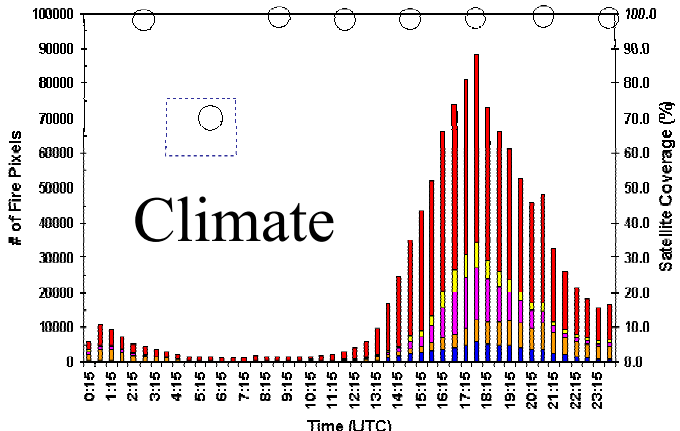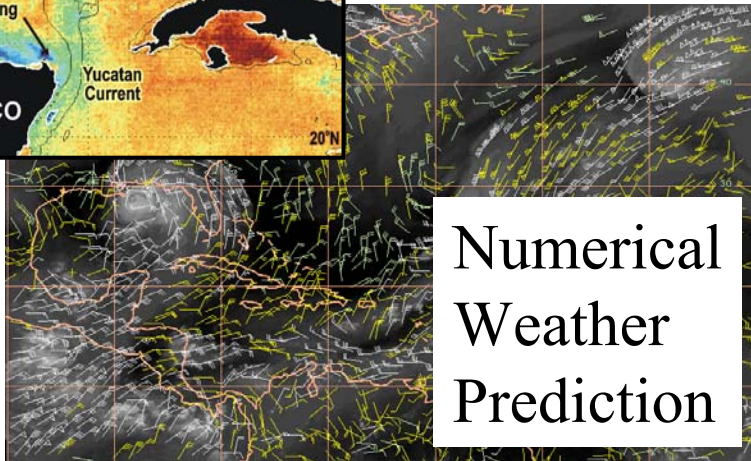Cooperative Institute for Meteorological Satellite Studies (CIMSS)

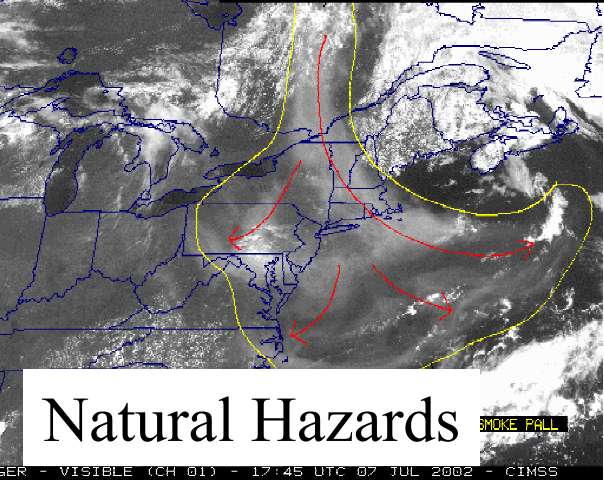Madison, WI

December 2004

CIMSS

UW-Madison

Current GOES Imagers -- a wide variety of Applications

Weather

Ocean

GOES SST Composite (C)
12 July 2000
LSU Earth Scan Lab

Numerical Weather Prediction

Hydrology/ Land Surface

Daily Insol (MJ day^-1 m^-2) for 27 Septe

Natural Hazards

Climate
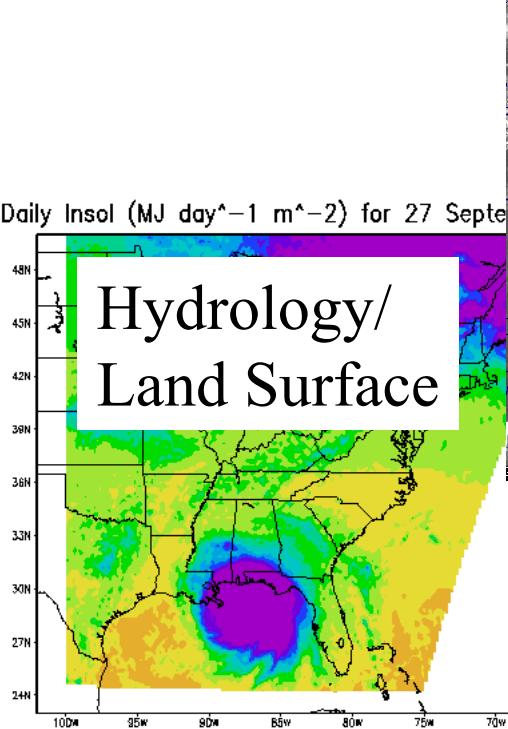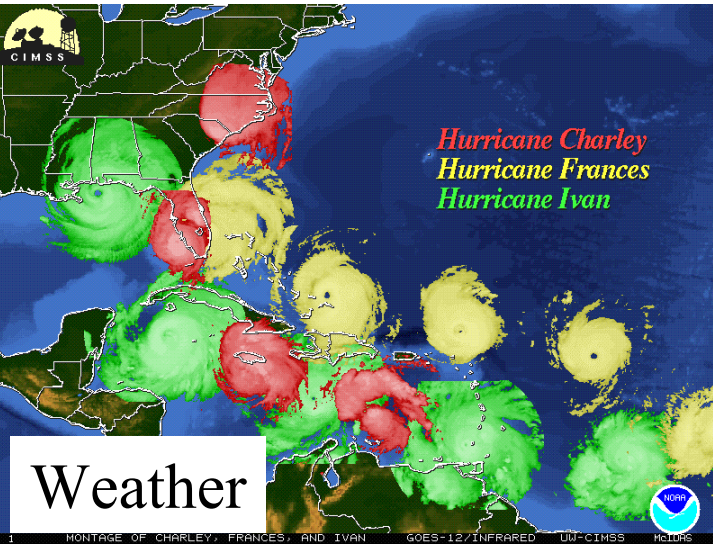
The Advanced Baseline Imager:

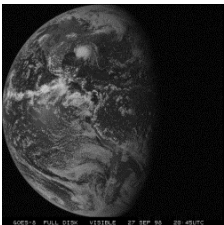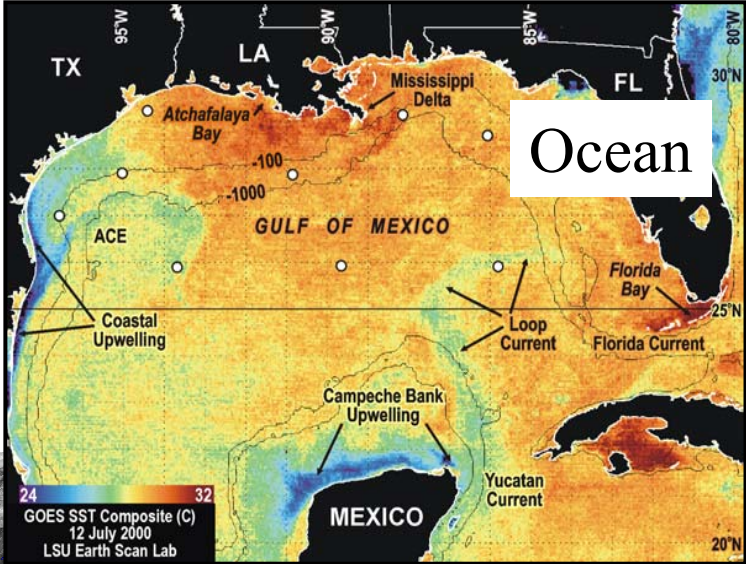|	ABI	Current
Spectral Coverage		
	16 bands	5 bands
Spatial resolution		
0.64 µm Visible	0.5 km	Approx. 1 km
Other Visible/nearIR	1.0 km	n/a
Bands (>2 µm)	2 km	Approx. 4 km
Spatial coverage		
Full disk	4 per hour	Every 3 hours
CONUS	12 per hour	~4 per hour
Visible		
On-orbit calibration	Yes	No

Visible and near-IR channels on the ABI
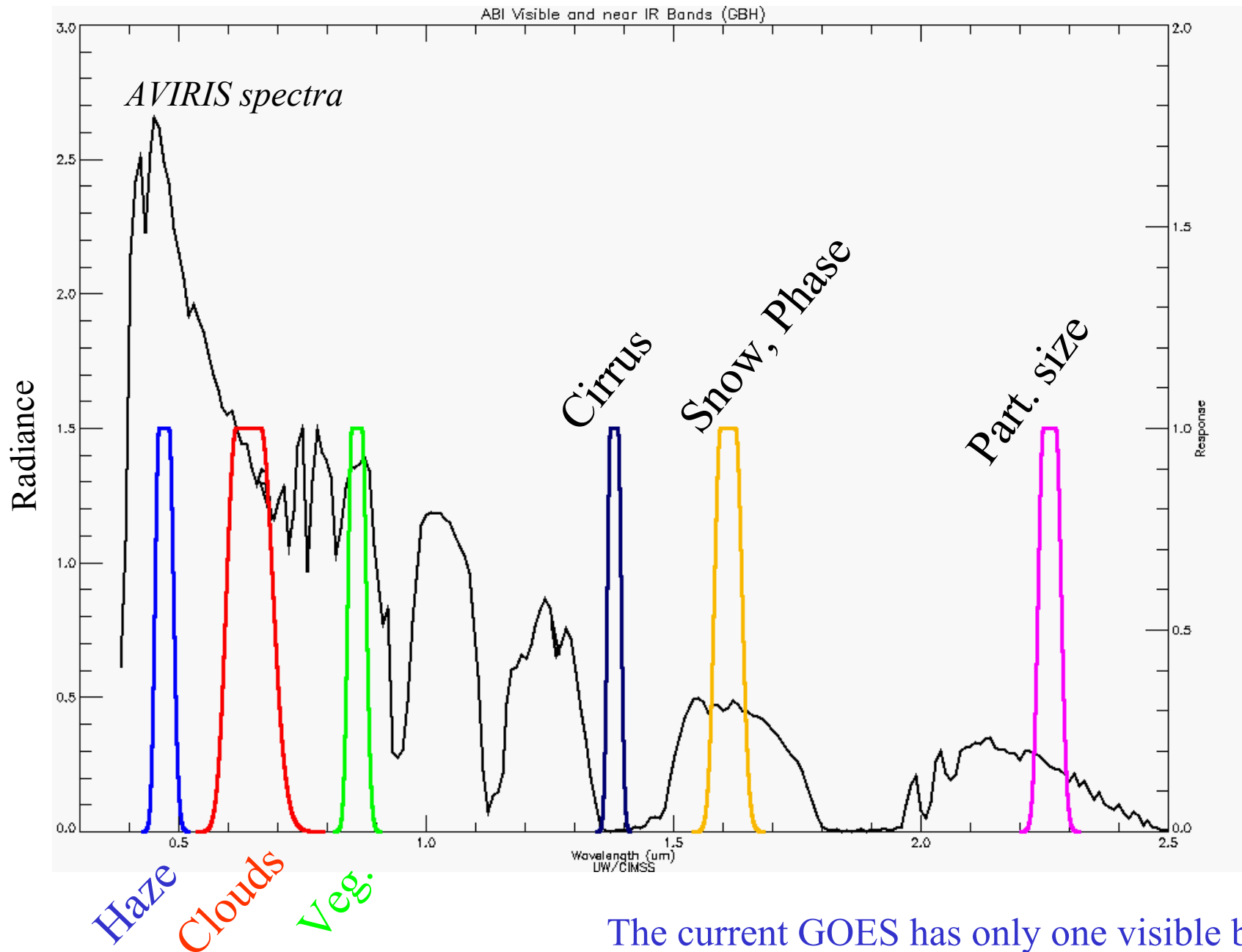
The current GOES has only one visible band.
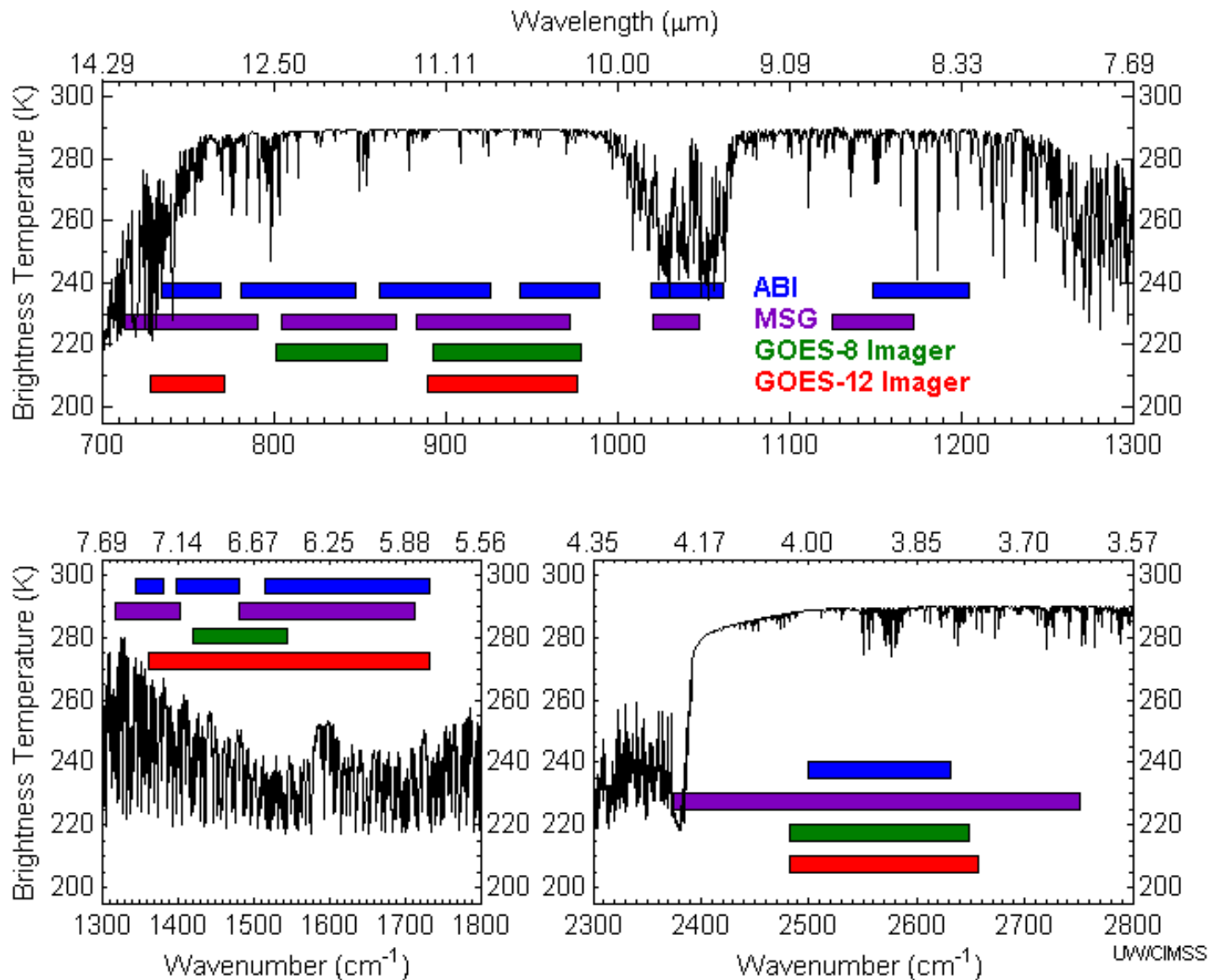
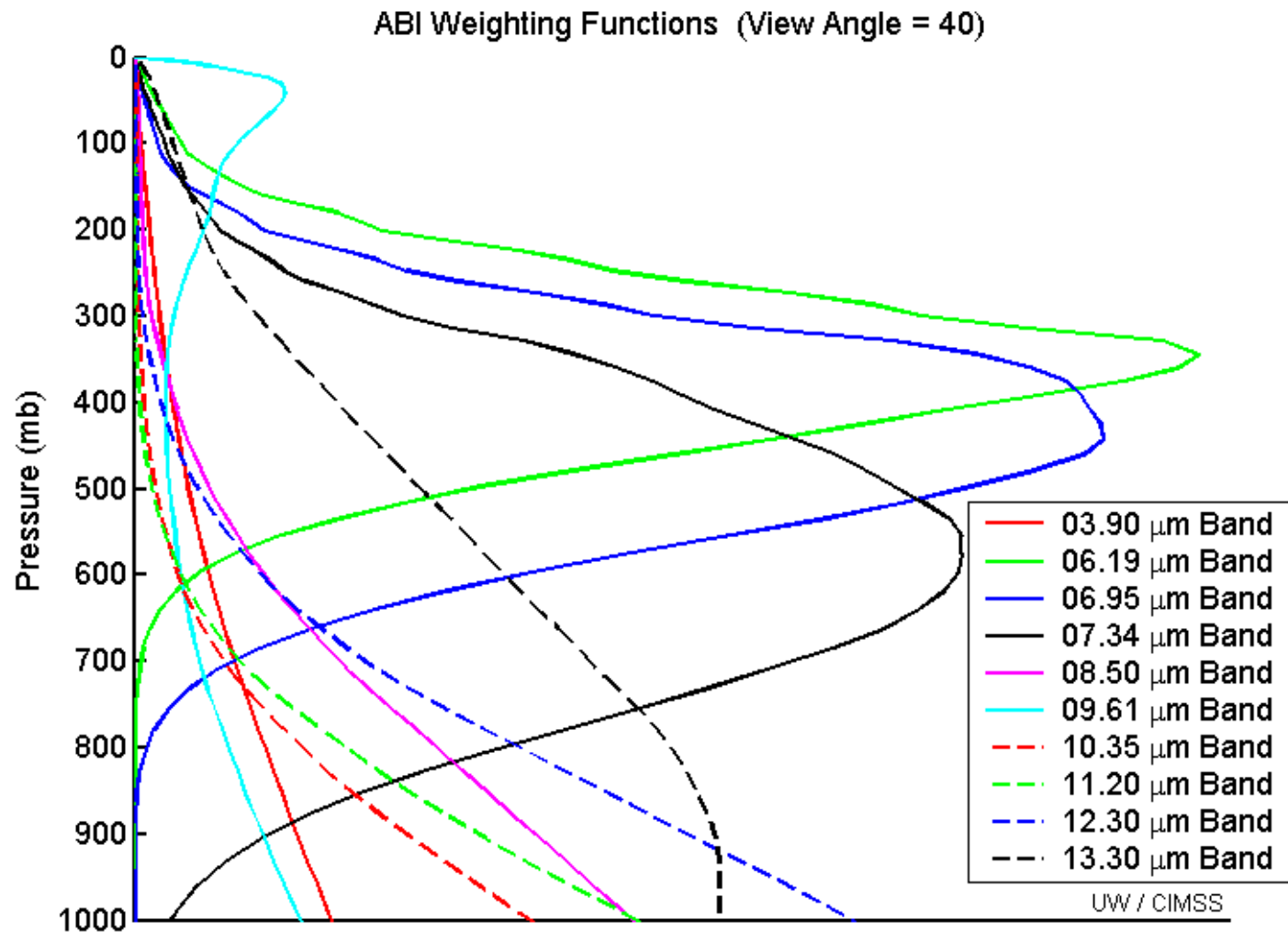While there are differences, there are also many similarities for the spectral bands on MET-8 and the Advanced Baseline Imager (ABI). Both the MET-8 and ABI have many more bands than the current operational imagers.

Weighting Functions for the IR channels on the ABI

ABI Weighting Functions (View Angle = 40)

Legend	
03.90 μm Band	(red)
06.19 μm Band	(green)
06.95 μm Band	(blue)
07.34 μm Band	(black)
08.50 μm Band	(magenta)
09.61 μm Band	(cyan)
10.35 μm Band	(red dashed)
11.20 μm Band	(green dashed)
12.30 μm Band	(blue dashed)
13.30 μm Band	(black dashed)

UW / CIMSS

Weighting functions for the standard atmosphere at a local zenith angle of 40 degrees.

ABI Bands

Future GOES Imager (ABI) Band	Wavelength Range (μm)	Central Wavelength (μm)	Sample Objective(s)
1	0.45-0.49	0.47	Daytime aerosol-over-land, Color imagery
2	0.59-0.69	0.64	Daytime clouds fog, insolation, winds
3	0.84-0.88	0.86	Daytime vegetation & aerosol-over-water, winds
4	1.365-1.395	1.38	Daytime cirrus cloud
5	1.58-1.64	1.61	Daytime cloud water, snow
6	2.235 - 2.285	2.26	Day land/cloud properties, particle size, vegetation
7	3.80-4.00	3.90	Sfc. & cloud/fog at night, fire
8	5.77-6.6	6.19	High-level atmospheric water vapor, winds, rainfall
9	6.75-7.15	6.95	Mid-level atmospheric water vapor, winds, rainfall
10	7.24-7.44	7.34	Lower-level water vapor, winds & SO_2
11	8.3-8.7	8.5	Total water for stability, cloud phase, dust, SO_2
12	9.42-9.8	9.61	Total ozone, turbulence, winds
13	10.1-10.6	10.35	Surface properties, low-level moisture & cloud
14	10.8-11.6	11.2	Total water for SST, clouds, rainfall
15	11.8-12.8	12.3	Total water & ash, SST
16	13.0-13.6	13.3	Air temp & cloud heights and amounts

Based on experience from:

Current GOES Imagers

ABI Bands

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Based on experience from:

Current GOES Imagers

MSG/AVHRR/ Sounder(s)

ABI Bands

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Based on experience from:

Current GOES Imagers

MSG/AVHRR/ Sounder(s)

MODIS, Aircraft, etc

Three-color composite (0.64, 1.6 and 11 μm) shows the low cloud over the snow and the water versus ice clouds.

Snow

Low cloud

TERRA MODIS - 1 KM - CH 01 06 31 - 18:32 UTC 03 DEC 2002 - CIMSS
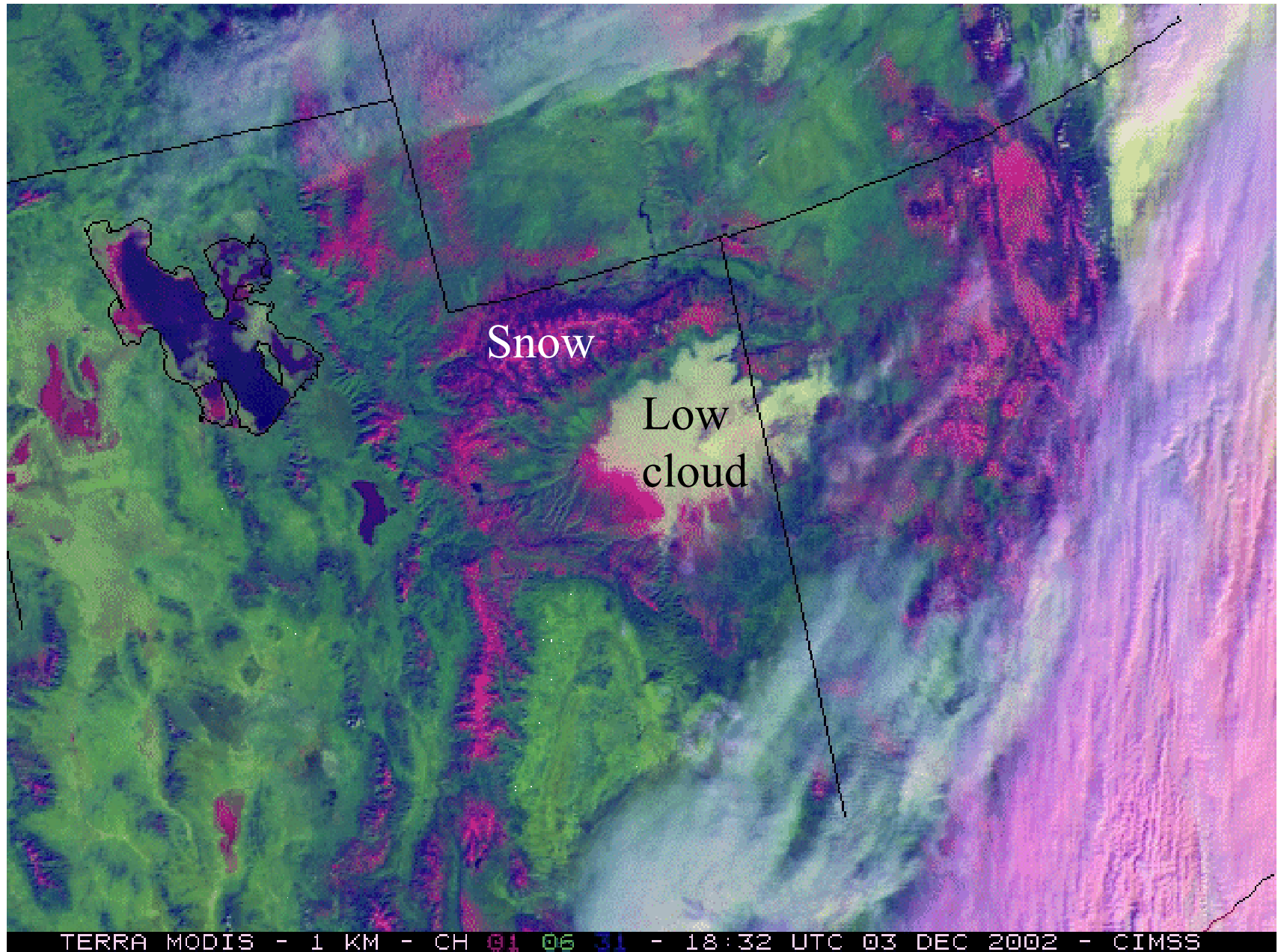
Volcanic Ash Plume: 11-12 and 8.5-11 μm images

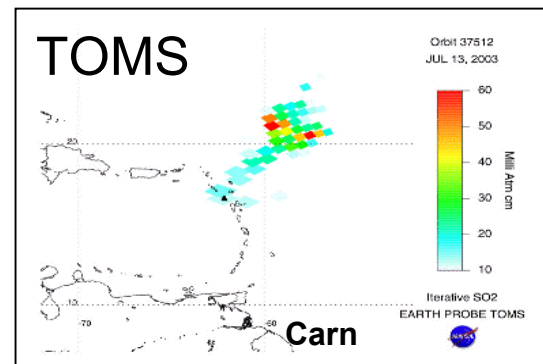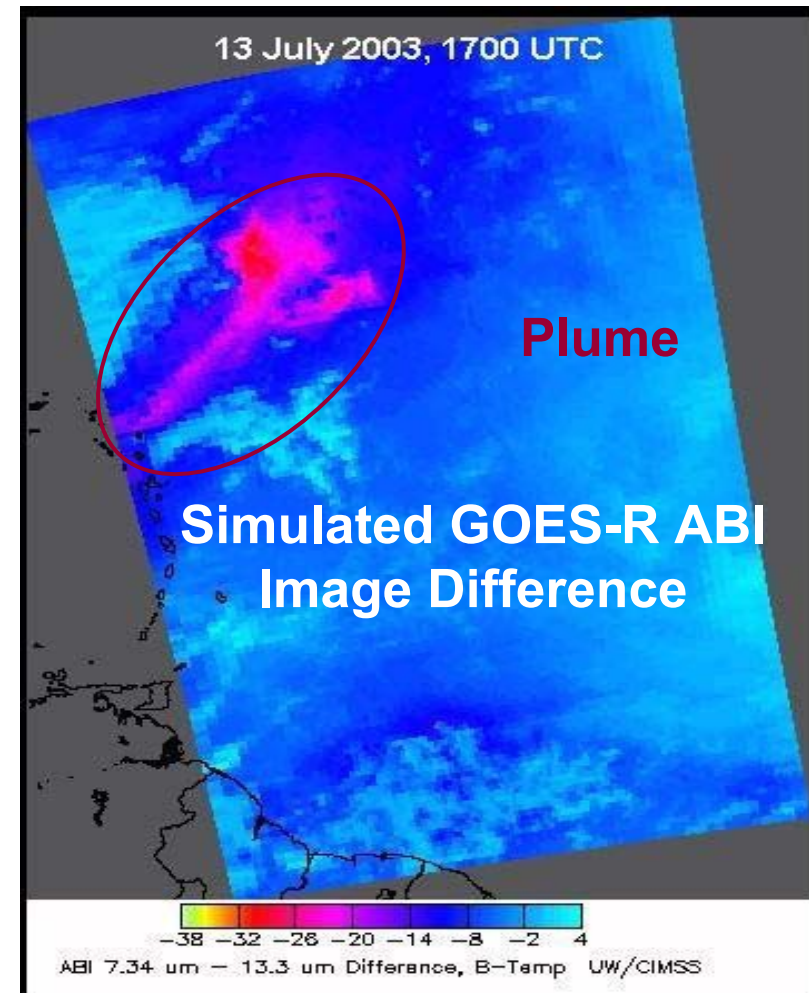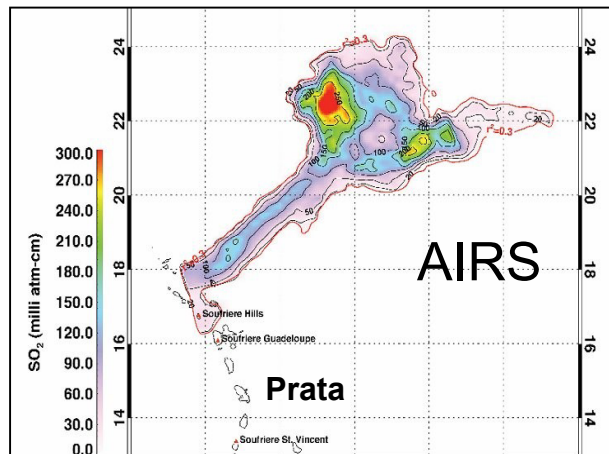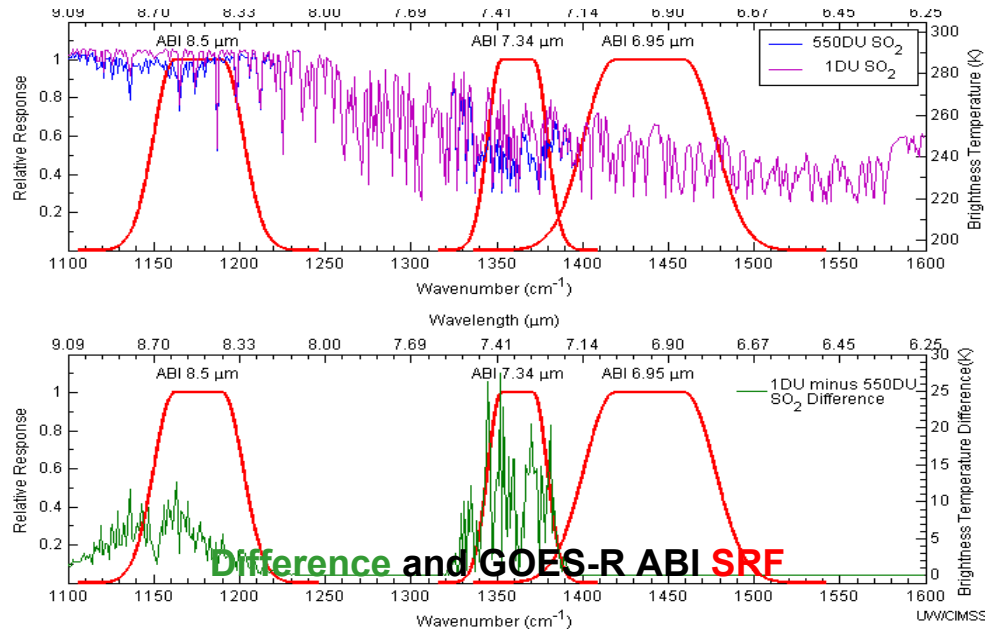Cleveland, Alaska   Photo by US Geological Survey

One day after the Mt. Cleveland eruption
20 February 2001, 0845 UTC

Simulated
ABI
(11-12 μm)

Simulated
ABI
(8.5-11 μm)

Poster…Ellrod

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Upper-level SO₂ Schreiner et al.

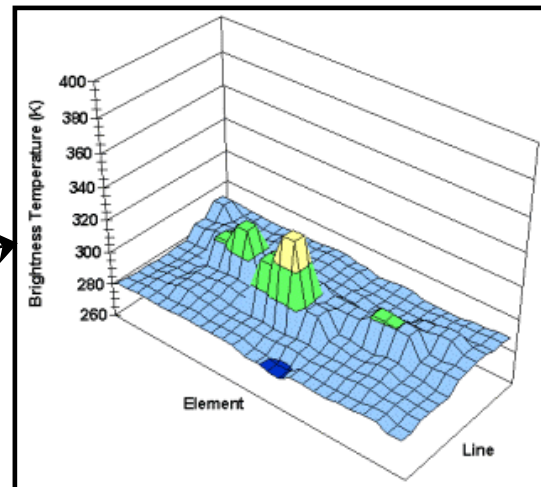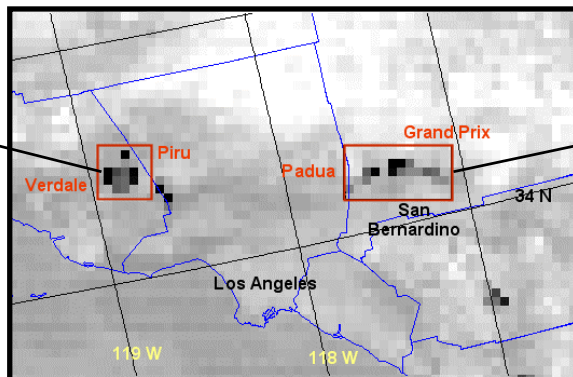Simulated IR spectrums for "normal" and "SO₂ enriched" atmosphere and spectral response functions
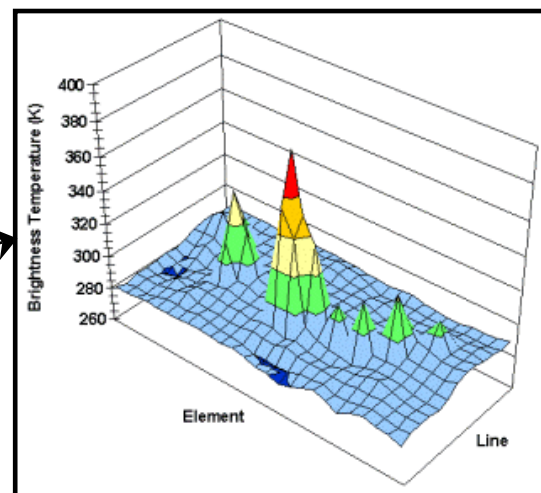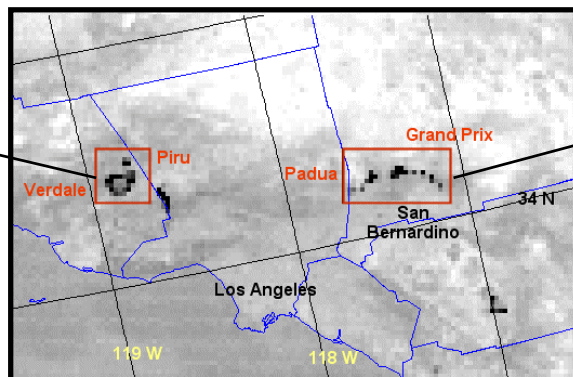

Difference and GOES-R ABI SRF

Plume

Simulated GOES-R ABI Image Difference

13 July 2003, 1700 UTC

ABI 7.34 um − 13.3 um Difference, B-Temp   UW/CIMSS

AIRS

Prata

TOMS

Carn

GOES-R and GOES-I/M Simulations of Southern California Fires

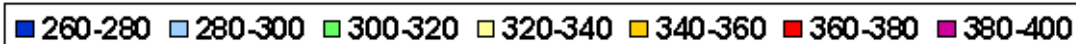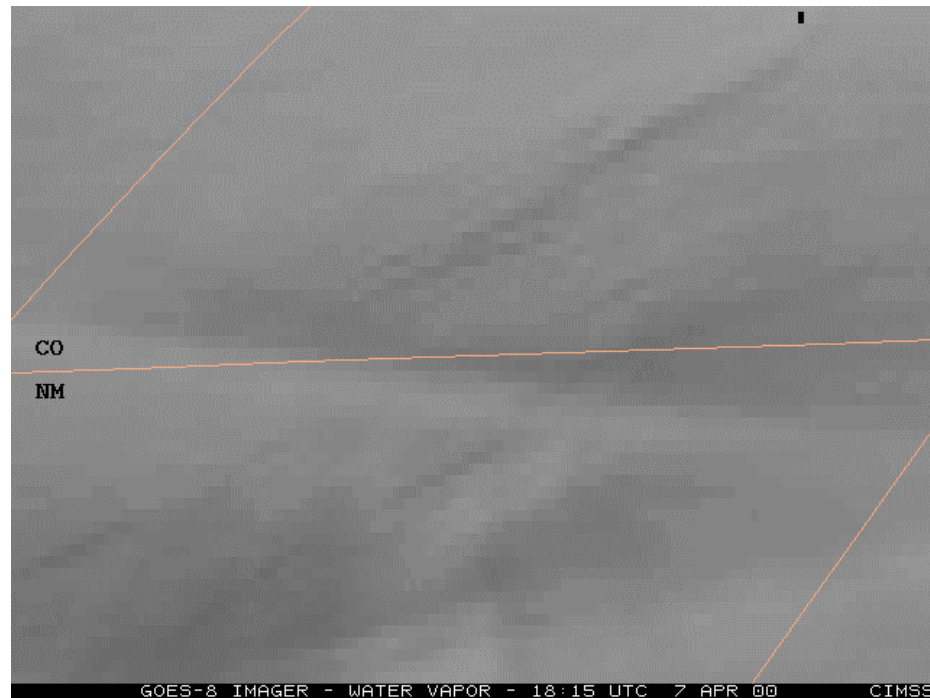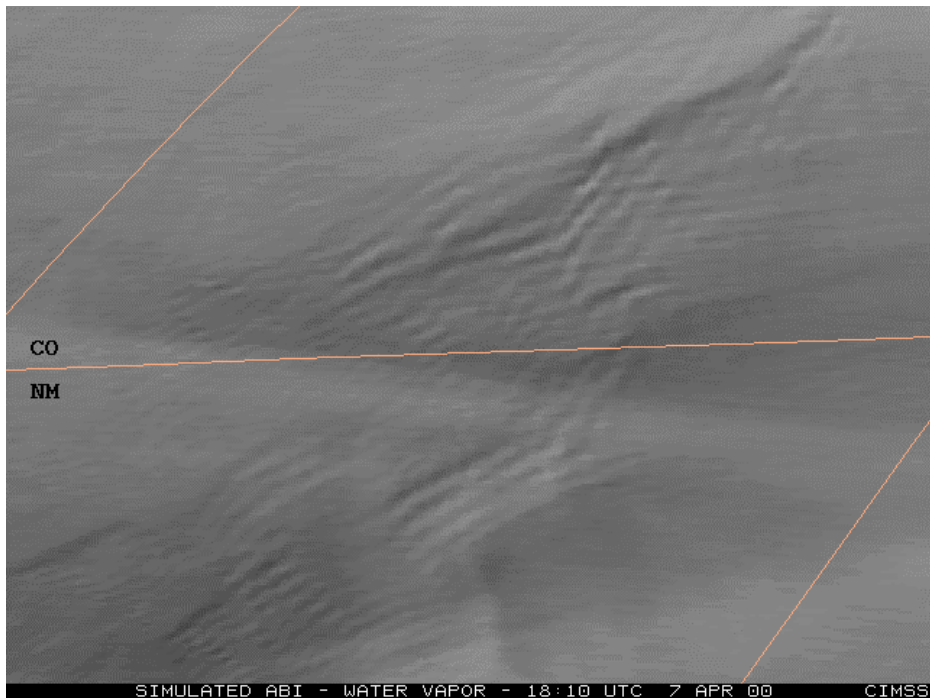# Mountain Waves in WV channel (6.7 μm)
## 7 April 2000, 1815 UTC

Simulated ABI   Actual GOES-8

Mountain waves over Colorado and New Mexico were induced by strong northwesterly flow associated with a pair of upper-tropospheric jet streaks moving across the elevated terrain of the southern and central Rocky Mountains. The mountain waves appear more well-defined over Colorado; in fact, several aircraft reported moderate to severe turbulence over that region.

Both images are shown in GOES projection.

UW/CIMSS
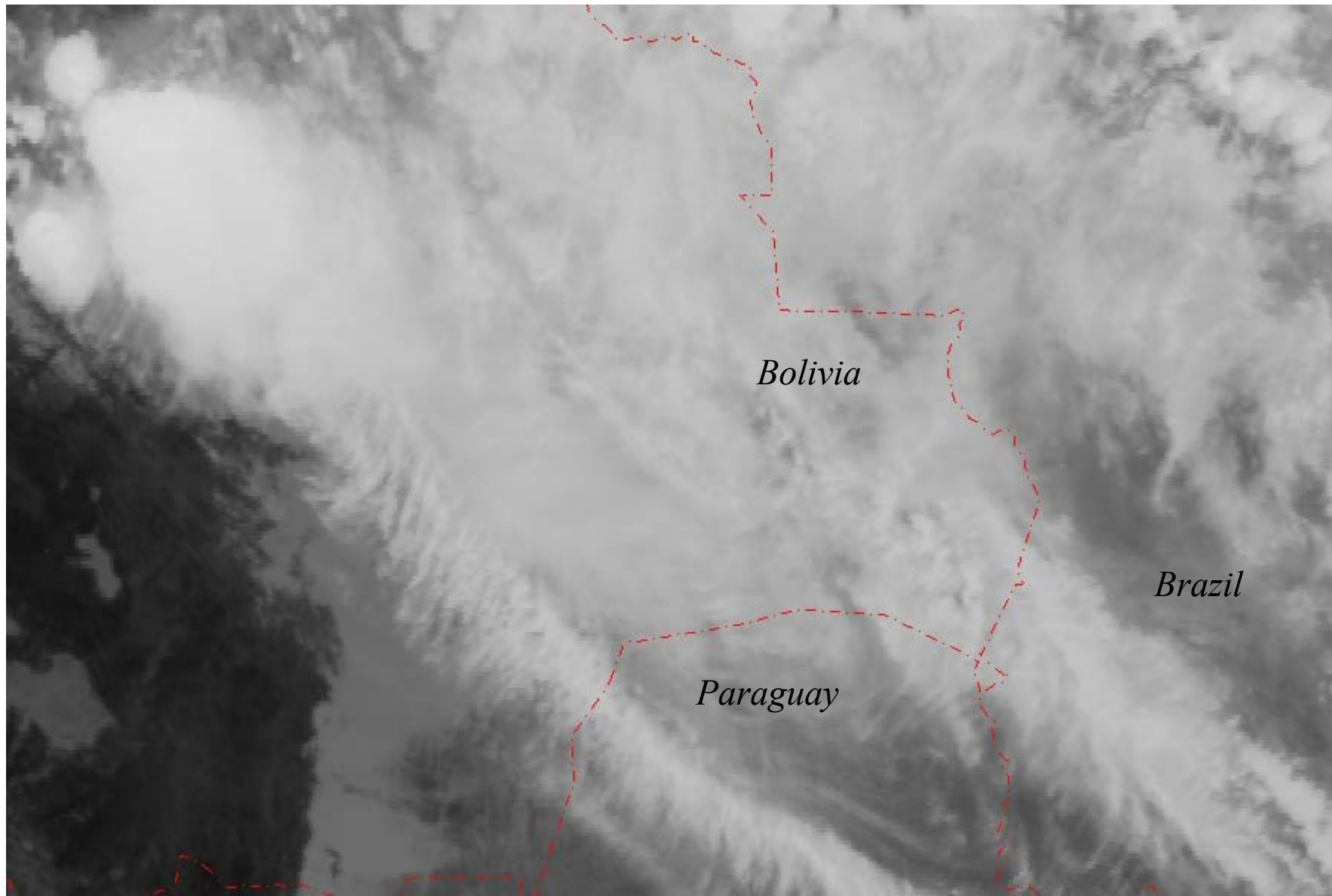
GOES-12 Imager ~4km 14:45UTC on 11/11/04 IR window
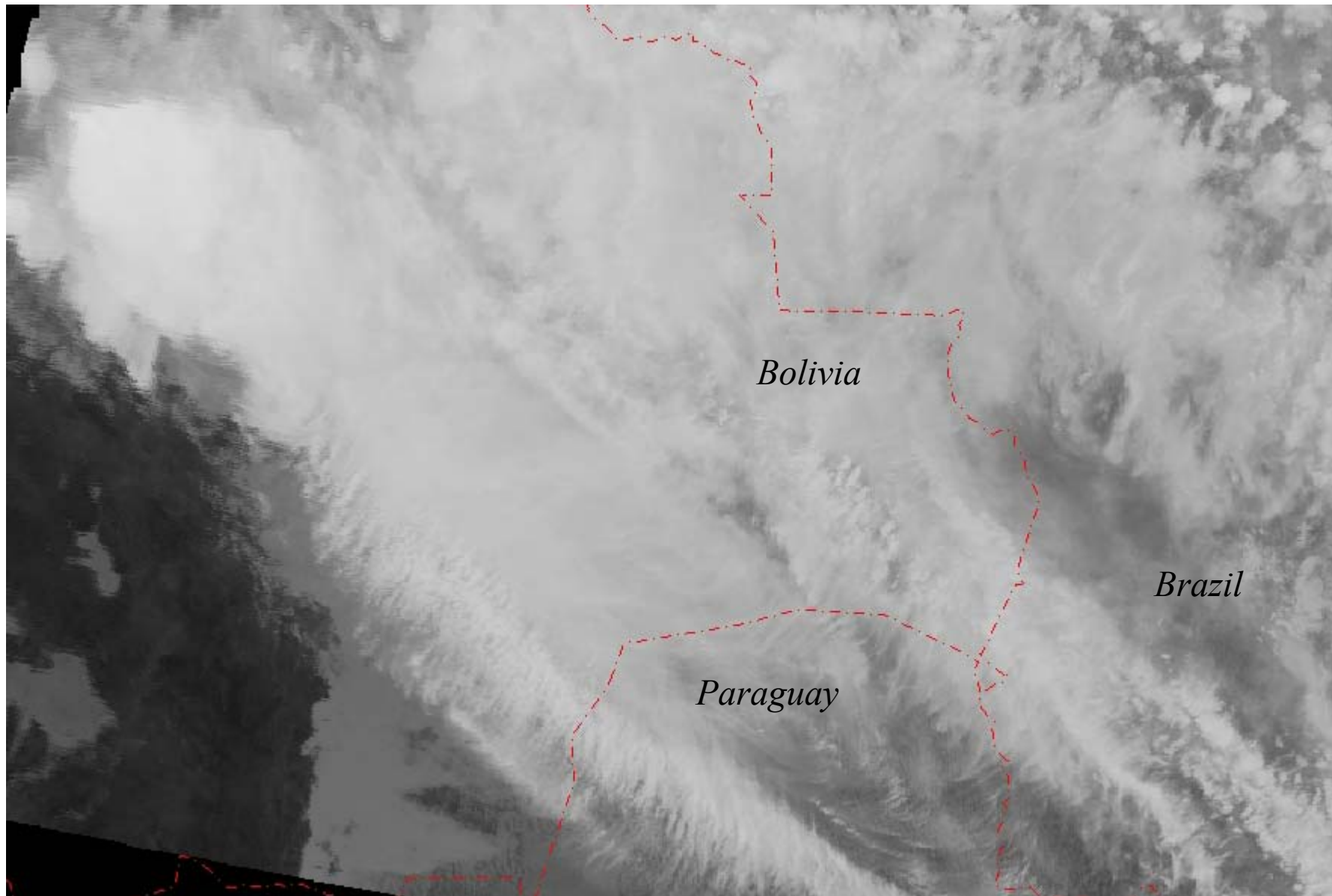
MODIS (Terra) – 2 km   14:05UTC on 11/11/04 IR window

Fog -- Based on GOES Imager 3.9 μm

5 March 2001 - Nocturnal Fog/Stratus Over the Northern Plains

ABI   4 minus 11 μm Difference

GOES-10   4 minus 11 μm Difference
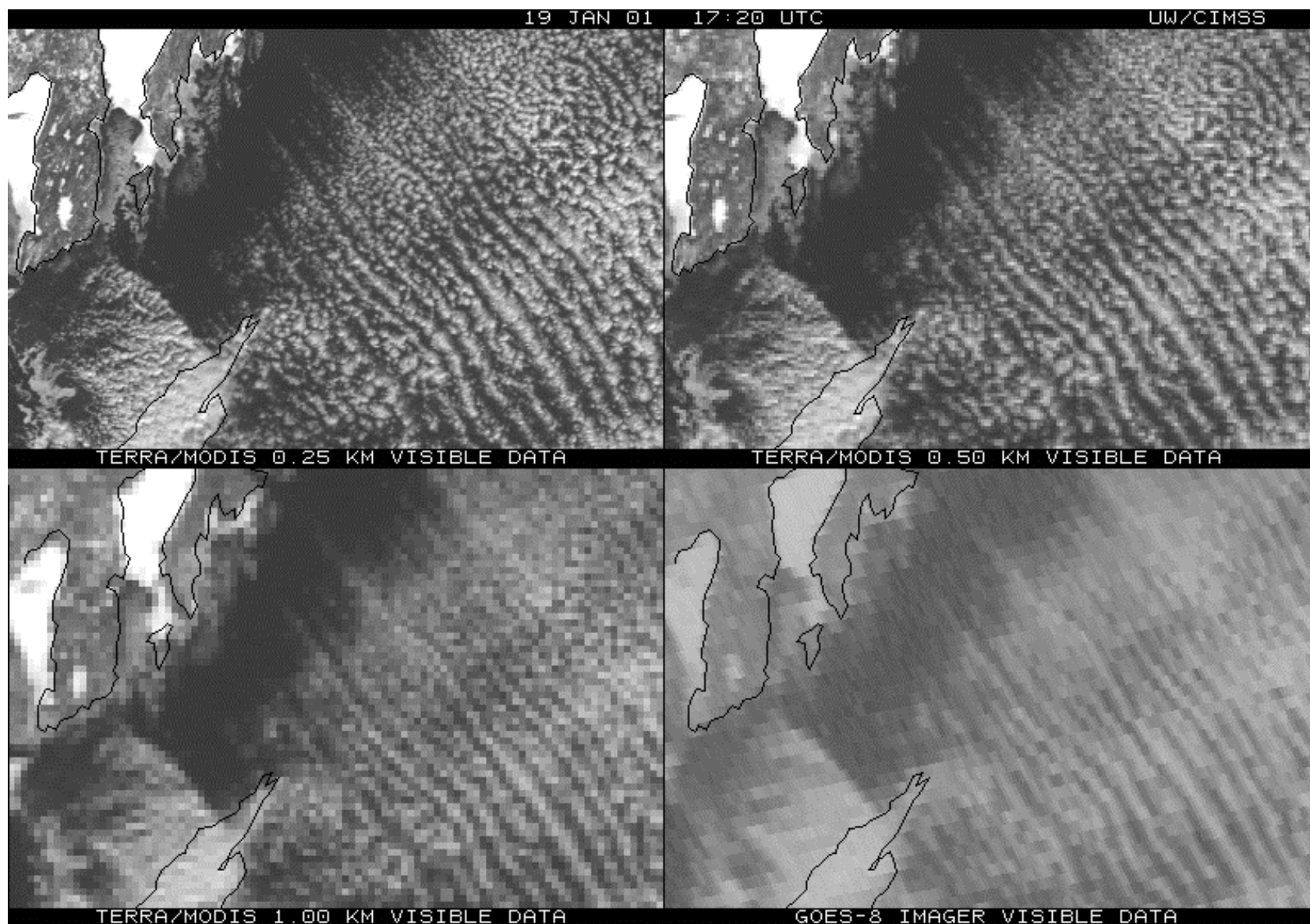

Both images are shown in the GOES projection.

Fog

UW/CIMSS

ABI image (from MODIS) shows greater detail in structure of fog.

Lake Effect Snow Bands: Visible

MODIS 0.25 km

MODIS 0.5 km

MODIS 1 km

GOES-8 1 km

19 January 2001, 1720 UTC

Higher Spatial Resolution GOES Channels

SIMULATED ABI - 10.7 IR - 04:30 UTC 25 MAY 2000 - CIMSS

−90 −80 −70 −60 −50 −40 −30 −20

concentric anvil-layer waves
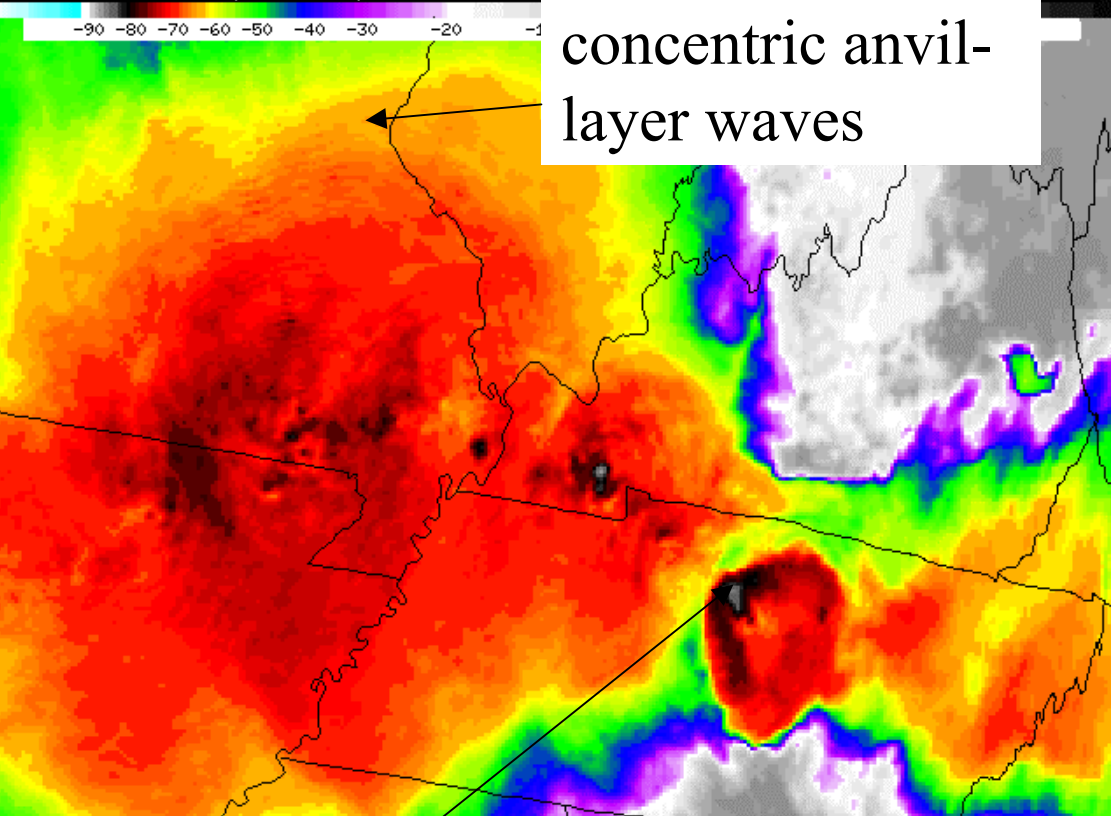
Simulated ABI
(from MODIS)

**Enhanced "V":
IR windows
May 25, 2000**

Enhanced "V"

Actual GOES

http://cimss.ssec.wisc.edu/goes/misc/000525.html

−30 +20 +10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 C

10.7 IR - 04:32 UTC 25 MAY 2000 - 1.0 KM - CIMSS
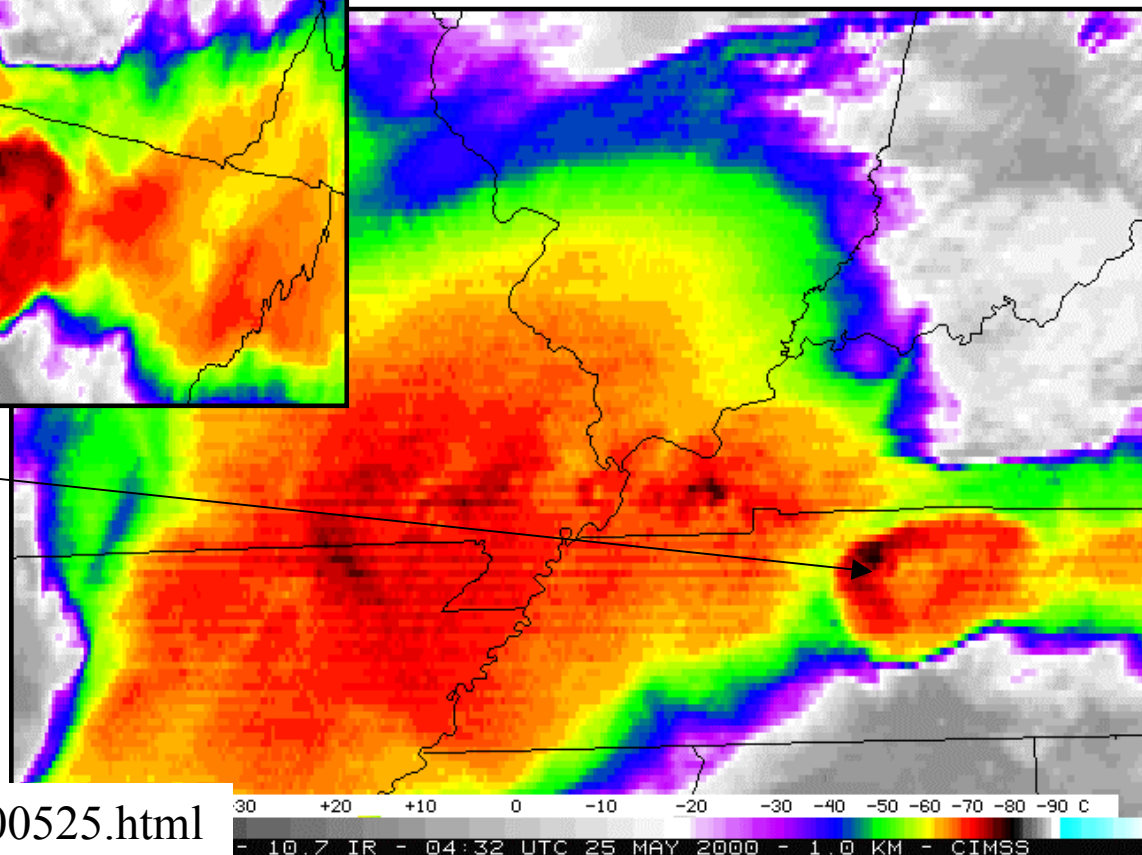
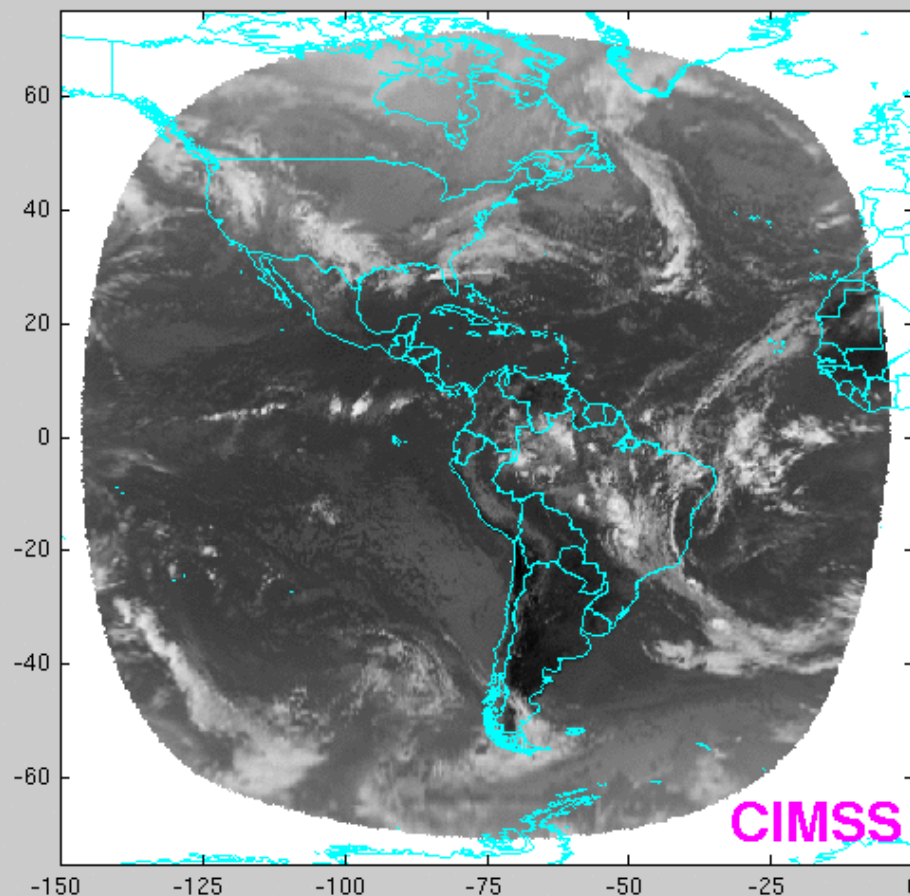# Current routine GOES and ABI temporal sampling Hemispheric View

ABI

GOES-East IR, 24-Feb-2004 14:45:00 UTC
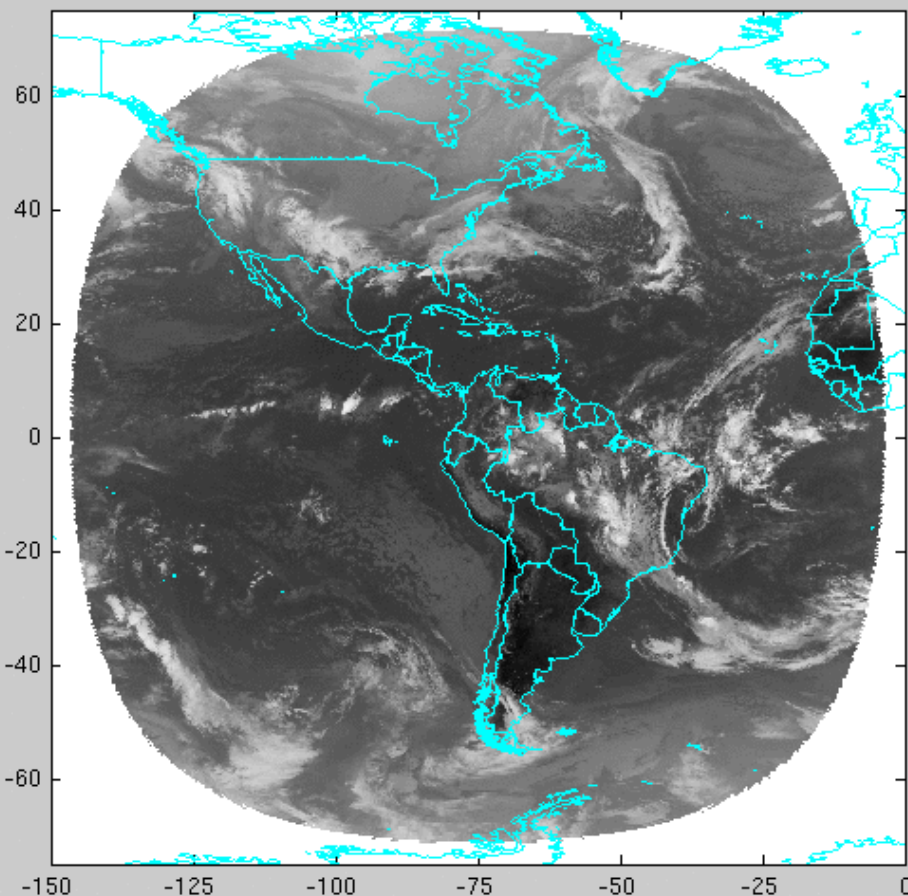
5-minute morph: 24-Feb-2004 14:45:00 UTC

CIMSS

This simulated GOES-R ABI loop was created by morphing between two actual GOES images. "Morphing" describes a broad category of digital image algorithms used to create smooth, seamless transitions between two or more images.

Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)

"0.47μm" (MODIS)	"0.64μm" (MODIS)	"0.86μm" (MODIS)	"1.38μm" (MODIS)
"1.61μm" (MET-8)	"2.26μm" (MODIS)	"3.9μm" (MODIS)	"6.19μm" (MET-8)
"6.95μm" (AIRS)	"7.34μm" (AIRS)	"8.5μm" (MODIS)	"9.61μm" (MODIS)
"10.35μm" (AIRS)	"11.2μm" (MODIS)	"12.3μm" (MODIS)	"13.3μm" (MODIS)

(reflectance)

(K)
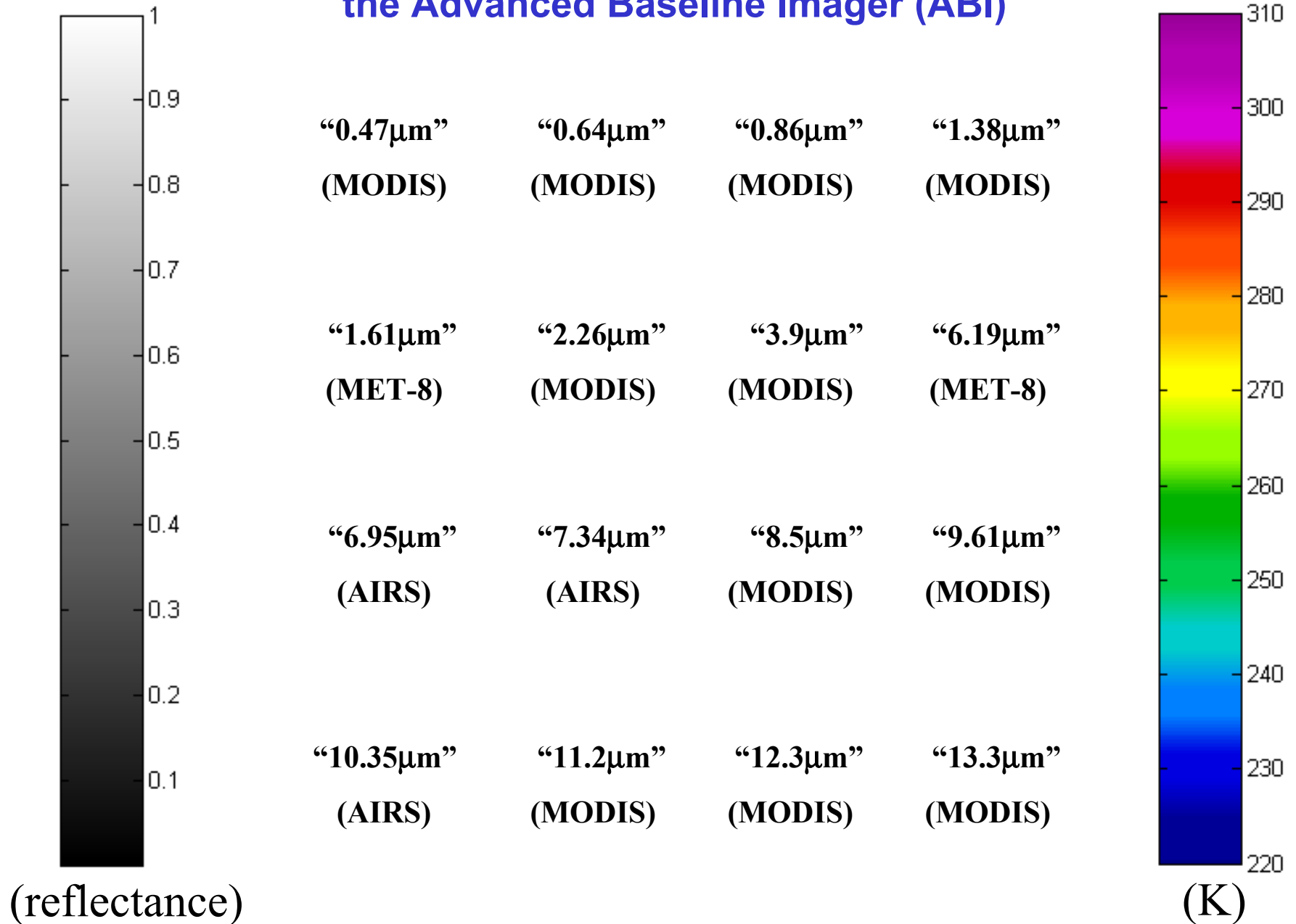
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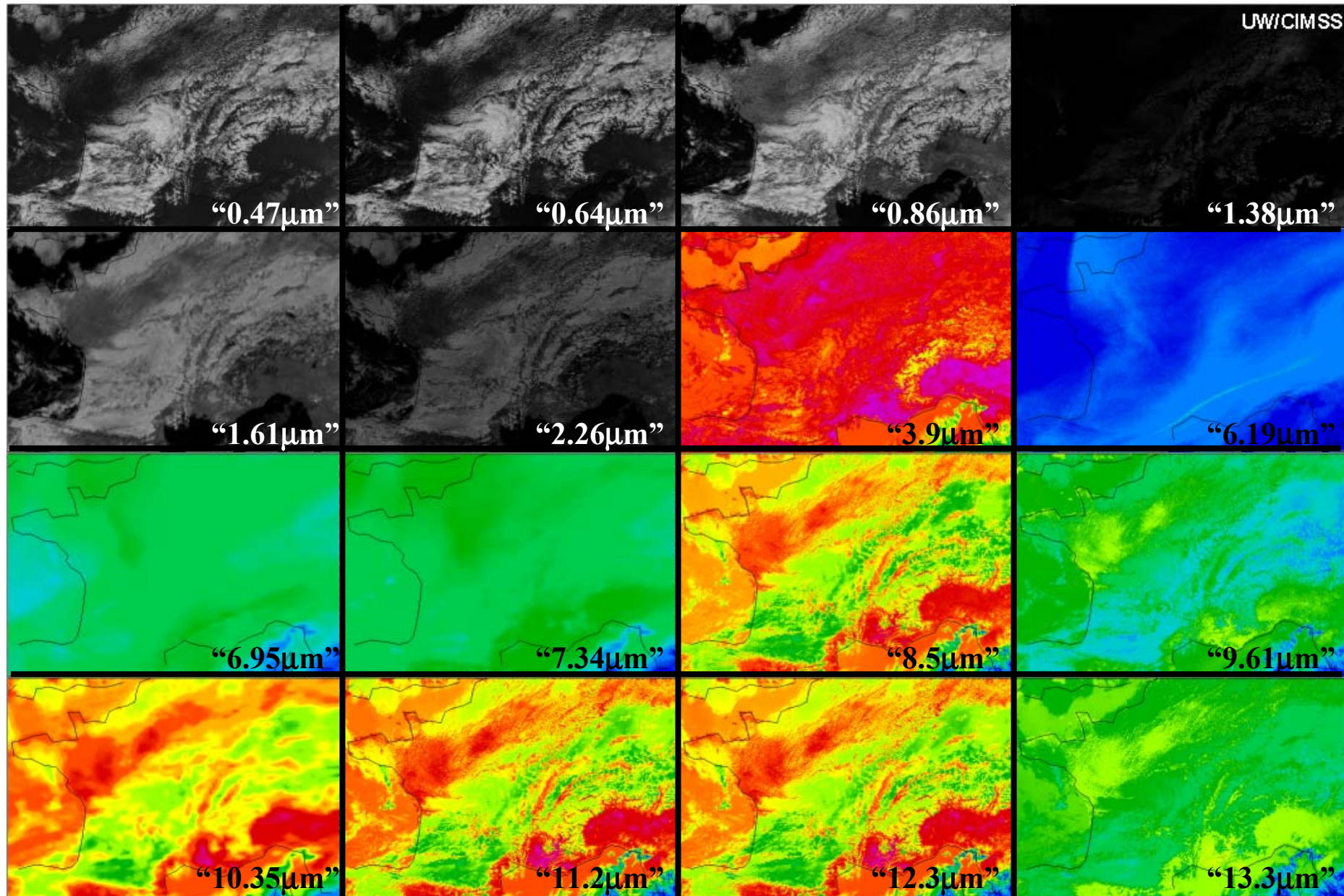
Similar bands on the GOES-12 Imager
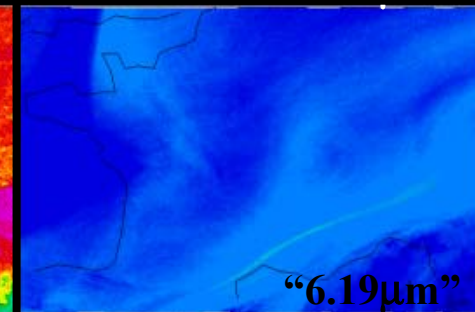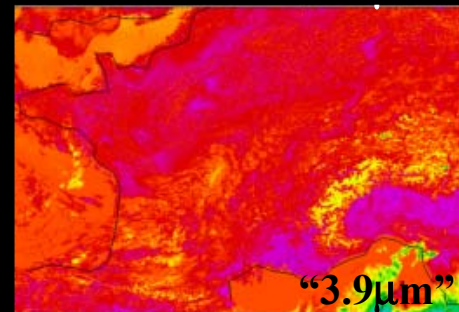
"0.64μm"

"3.9μm"

"6.19μm"

"11.2μm"

"13.3μm"

Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)
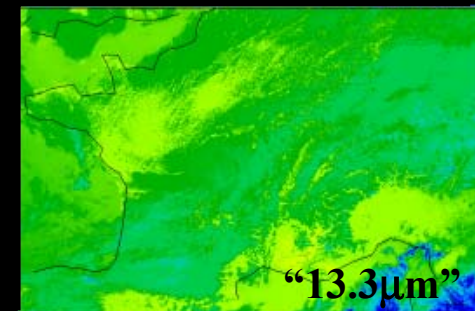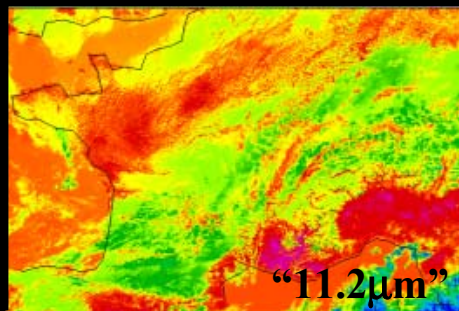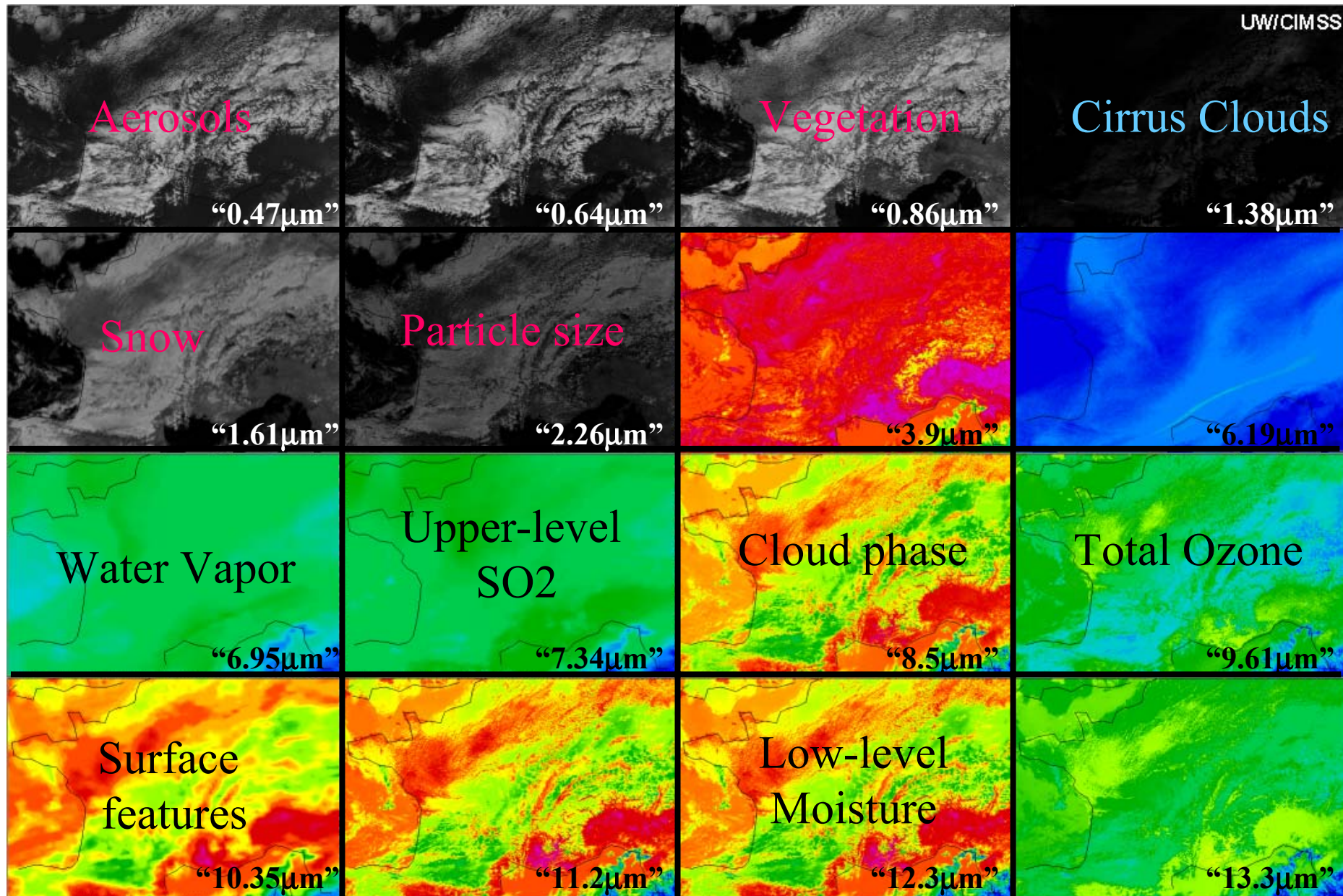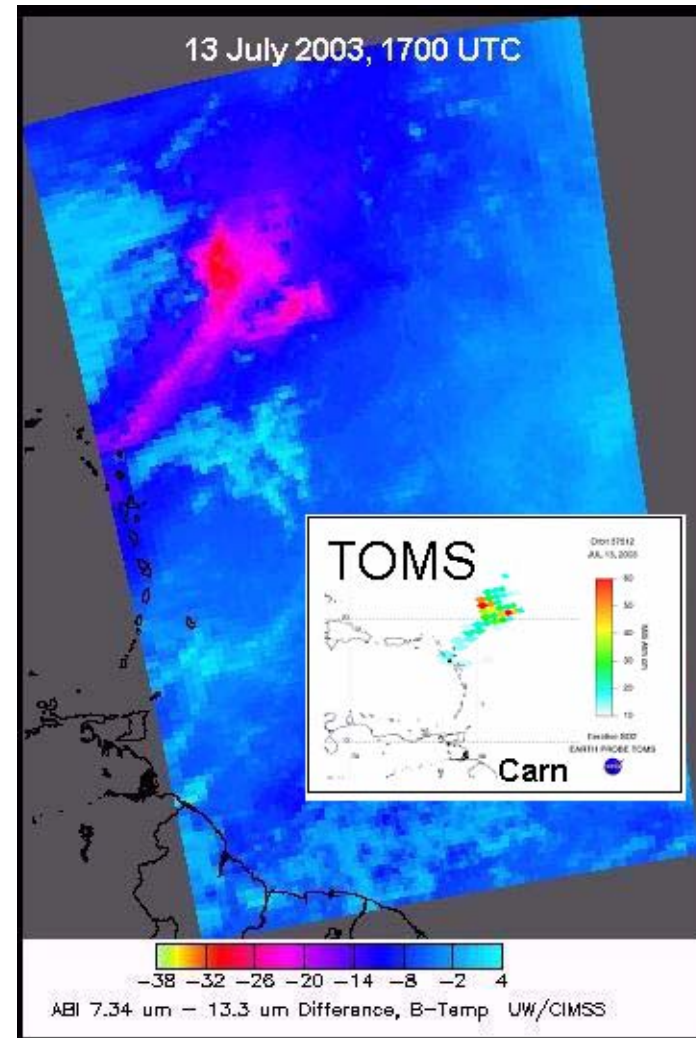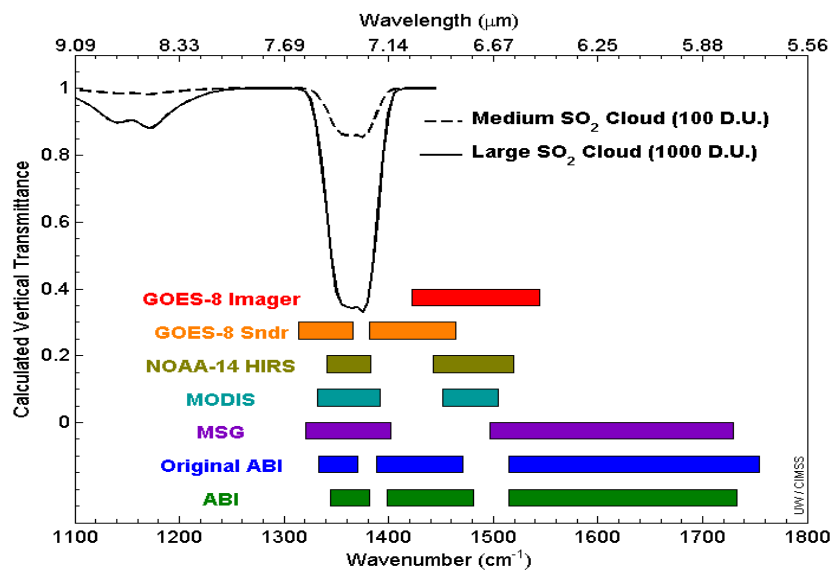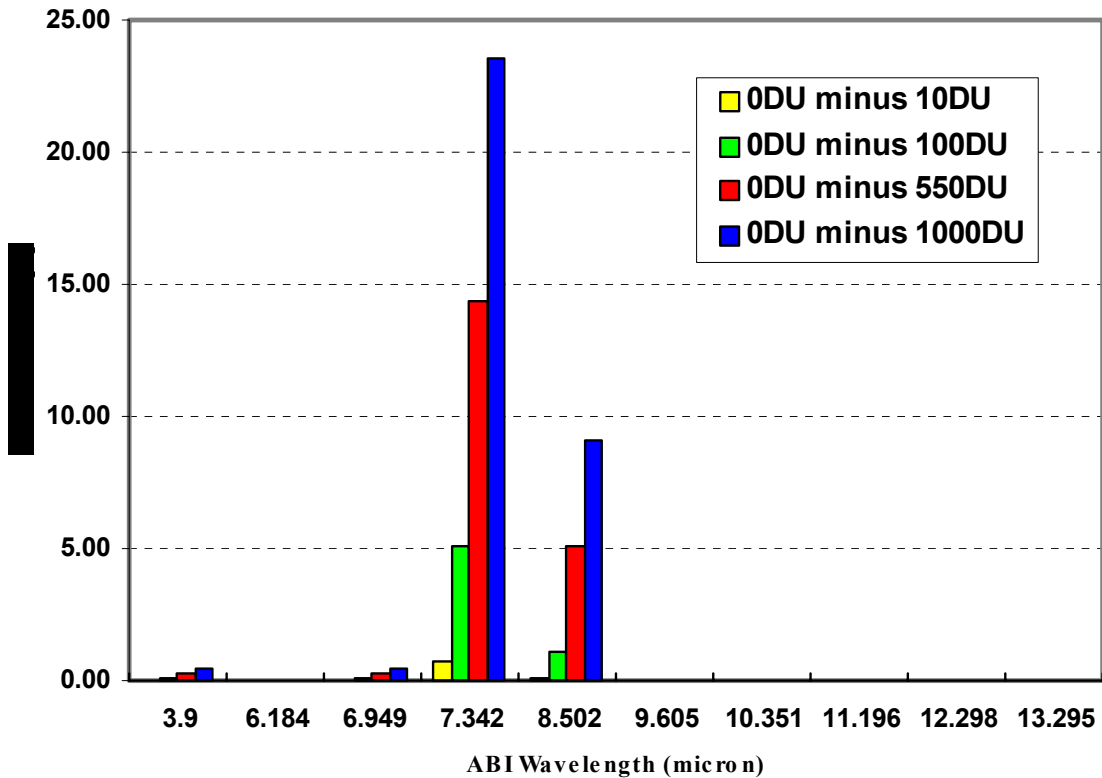
Detection of Temperature Inversions Possible with Interferometer

Brightness Temperature (K)

CO2 and H2O lines from IMG over Texas and Ontario

Texas

**Spikes down -
Cooling with height**
(No inversion)

Ontario

**Spikes up -
Heating with height**
(low-level inversion)

GOES   GOES

Wavenumber (cm⁻¹)

Brightness Temperature (K)

Wavenumber (cm-1)
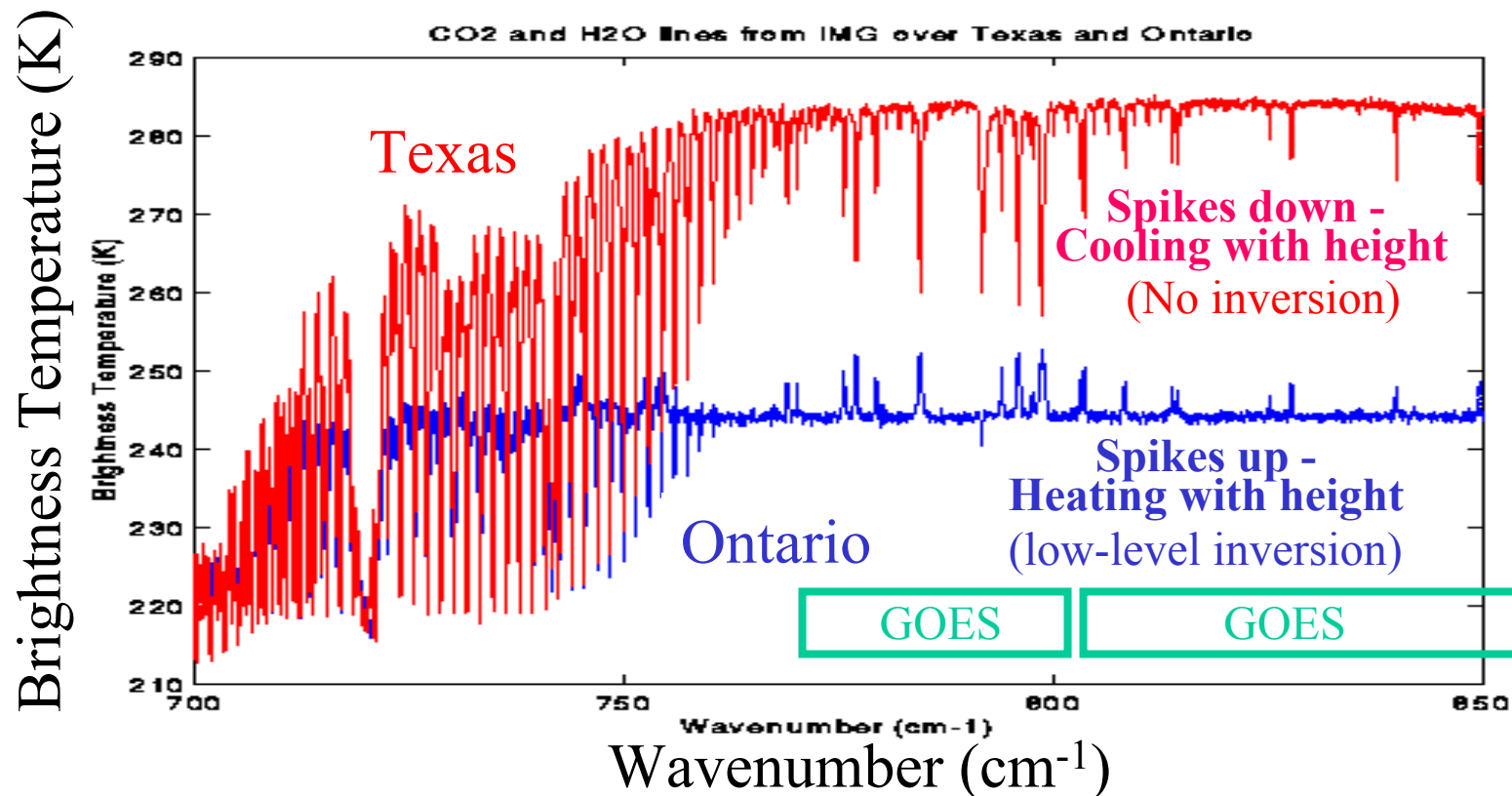
The detection of inversions is critical for severe weather forecasting. Combined with improved low-level moisture depiction, critical ingredients for night-time severe storm development over the Plains can be monitored. Knowing if there is an inversion can also help improve the profiles estimates.

Improved products will be realized from combinations of ABI *and* HES (Hyperspectral Environmental Suite) data (IR and Visible/near IR on the HES-Coastal Water)!

Spatial resolution

Cloud clearing

ABI

Surface emissivity

Temporal resolution

HES

Spectral coverage

Spectral resolution
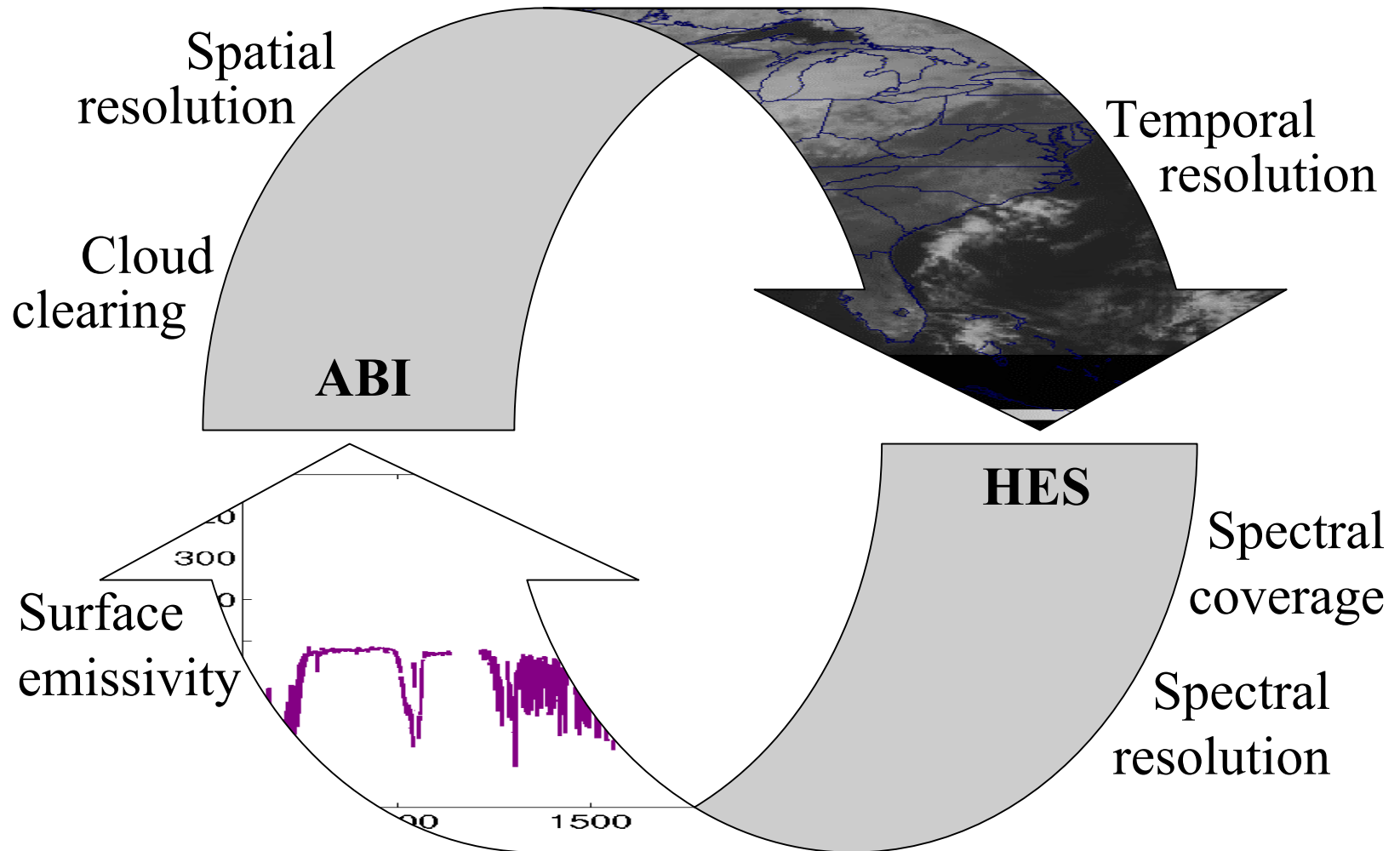
Much improved spatial coverage with the HES Sounder

Current GOES Sounder coverage in one hour

GOES-R HES Sounder coverage in one hour

Cloud Top Pressure

CLEAR — 900 800 700 600 500 400 300 200 MB

GOES-12 IMAGER   CLOUD TOP PRESSURE   3 MAR 04   15:00UTC

CIMSS

GOES R Observational Requirements*
(instrument capabilities on day 1)

Absorbed Shortwave Radiation	Downward Solar Insolation	Rainfall Potential
Aerosol Detection	Dust/Aerosol	Rainfall Rate/QPE
Aerosol Particle Size	Energetic Heavy Ions	Reflected Solar Insolation
Aircraft Icing Threat	Enhanced "V"/Overshooting Top Detection	Sea & Lake Ice/Age
Atmospheric Vertical Moisture Profile	Fire / Hot Spot Imagery	Sea & Lake Ice/Concentration
Atmospheric Vertical Temperature Profile	Flood/Standing Water	Sea & Lake Ice/ Displacement and Direction
Capping Inversion Information	Geomagnetic Field	Sea & Lake Ice/Extent and Characterization
Clear Sky Masks	Hurricane Intensity	Sea Surface Temps
Cloud & Moisture Imagery	Ice Cover/ Landlocked	Snow Cover
Cloud Ice Water Path	Imagery: All-Wx/Day-Nite	Snow Depth
Cloud Imagery	Land Surface (Skin) Temperature	SO_2 Concentration
Cloud Layers / Heights and Thickness	Lightning Detection	Solar and Galactic Protons
Cloud Liquid Water	Low Cloud and Fog	Solar Flux: EUV
Cloud Optical Depth	Mag Electrons & Protons: Low Energy	Solar Flux: X-Ray
Cloud Particle Size Distribution	Mag Electrons & Protons: Med & High Energy	Solar Imagery
Cloud Top Height	Microburst Winds	Surface Albedo
Cloud Top Phase	Moisture Flux	Surface Emissivity
Cloud Top Pressure	Ocean Color	Suspended Matter
Cloud Top Temperature	Ocean Currents	Total Precipitable Water
Cloud Type	Ocean Optical Properties	Total Water Content
CO Concentration	Ocean Turbidity	Turbulence
Convection Initiation	Ozone Layers	Upward Longwave Radiation
Currents	Ozone Total	Vegetation Fraction: Green
Derived Motion Winds	Pressure Profile	Vegetation Index
Derived Stability Indices	Probability of Rainfall	Visibility
Downward Longwave Radiation	Radiances	Volcanic Ash

ABI – Advanced Baseline Imager	HES – Hyperspectral Environmental Suite	SEM – Space Environment Monitor	SXI – Solar X-Ray Imager	GLM – GOES Lightning Mapper

* Does not reflect individual geographic coverage requirements.

Prepared By: L.O'Connor 02/06/2004

Total Downlink

Mbps

140
120
100
80
60
40
20
0

1 : 45

Rebroadcast

Mbps

25
20
15
10
5
0

1 : 9

Total Products

160
140
120
100
80
60
40
20
0

1 : 4
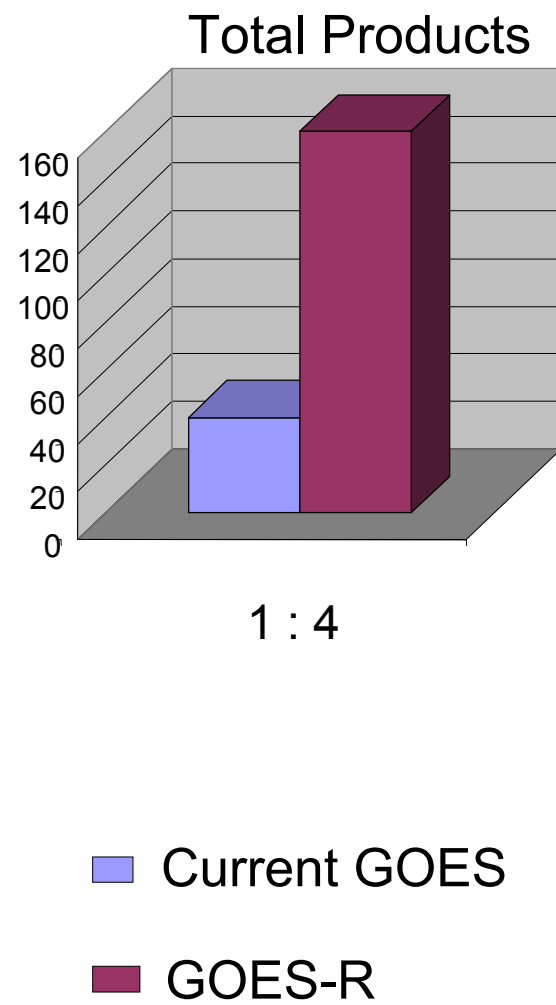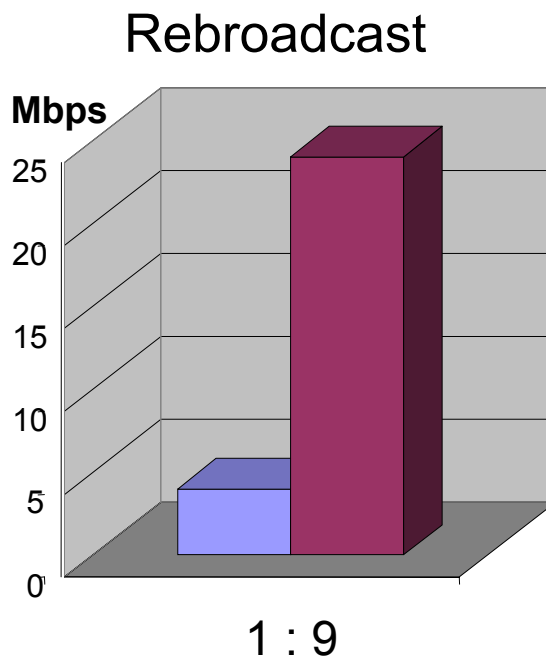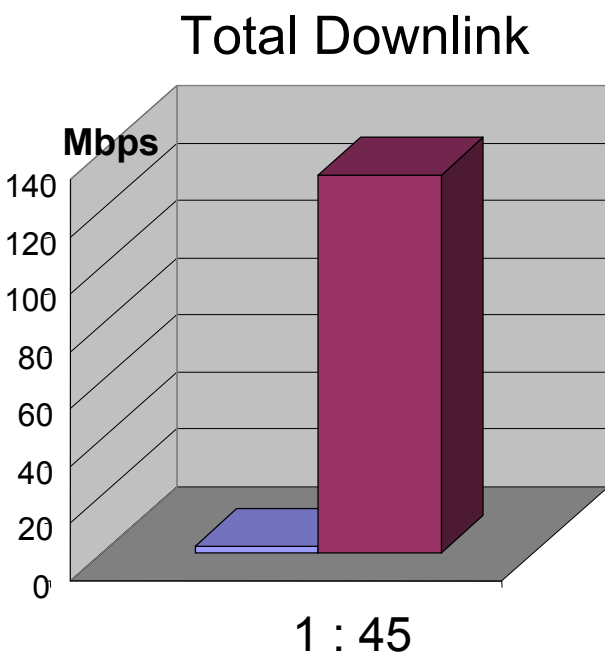
■ Current GOES

■ GOES-R

What we know

- Data distribution is very important
- There are a large number of current GVAR reception sites, more sites are being added
- These are a combination of fixed and mobile sites.
- There is a wide range of current users needs
- GOES-R instrument data rates increase by approximately two orders of magnitude over current instruments
- Data compression can help to reduce data rates (and hence distribute more data) while preserving information

What we know (Continued)

- Data (raw) downlink most likely will be in the X-band
- Data re-broadcast will most likely be in the L-band
- GOES Re-Broadcast (GRB) format will be different than todays GVAR
- There will be some form of satellite re-broadcast
- A tunable range of data compression options, depending on data, is ideal.
- Data compression techniques will continue to improve

What we do not know

- Data formats
- Data rate of re-broadcast data
- Contents of re-broadcast data
- Type or Amount of data compression
- Relationship between amount of data "pushed" versus "pulled"
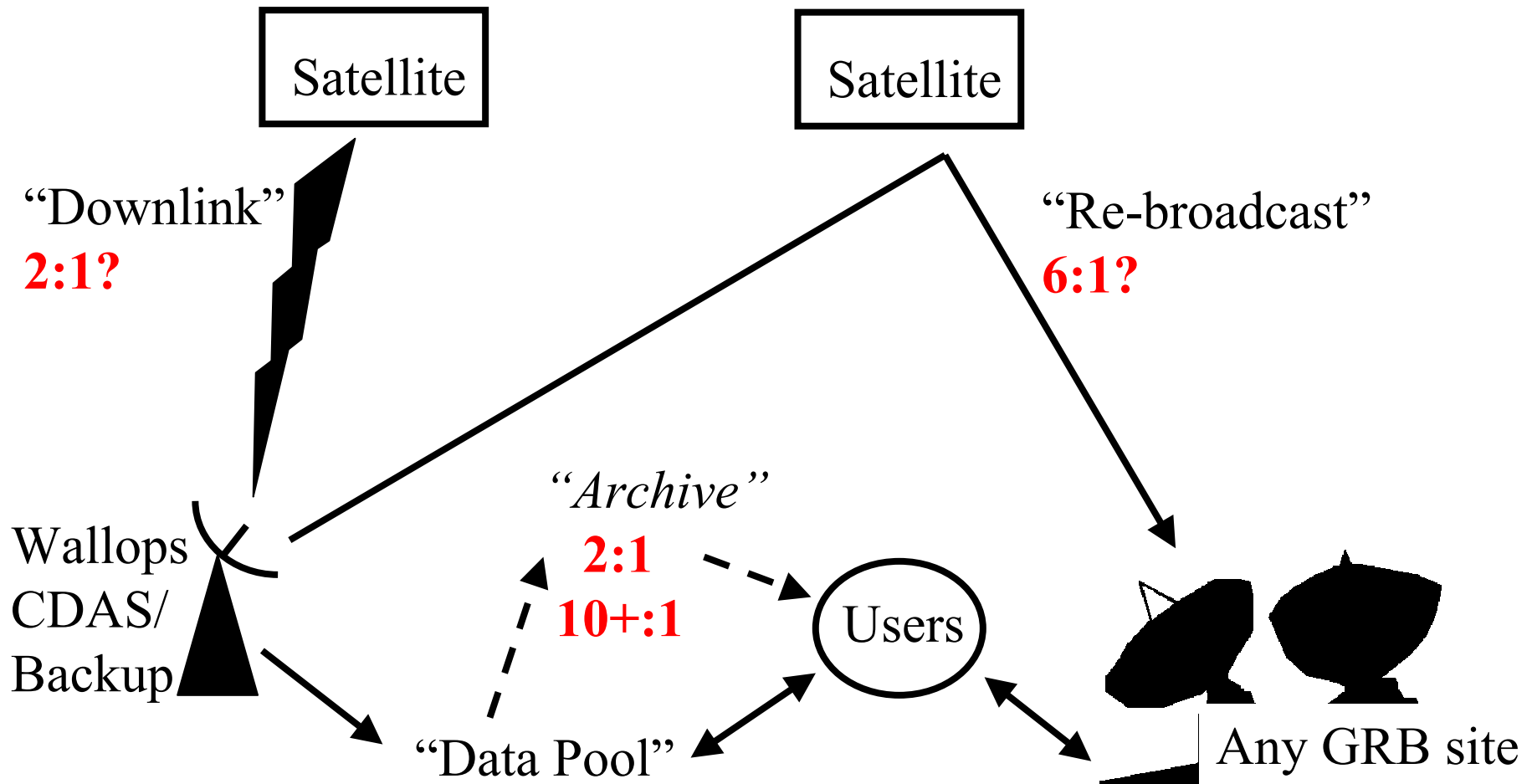- Etc.

Future GOES Rebroadcast

- GRB system is extension of current GVAR system for GOES-R era
  - Serve users in Near RealTime throughout western hemisphere
  - Current GVAR mainly only rebroadcasts radiance data; GRB may/could rebroadcast both radiances and some products

- GRB system is payload service, separate from any direct service (LRIT, DCPI/R, EMWIN, and SAR)
  - GRB is needed to make a large amount of data available to a wide range of users (both geographically and in terms of data use) in a cost efficient manner

- Main difference between GVAR and GRB:
  - Due to new, large data rates for the instruments currently planned for GOES-R, the GRB system will not realistically be able to transmit all level 1b data without data compression

Possible GOES ReBroadcast System

Data compression can have applications in a number of areas:
- downlink   –rebroadcast   - distribution   - archive

Satellite

Satellite

"Downlink"
2:1?

"Re-broadcast"
6:1?

Wallops
CDAS/
Backup

"Archive"
2:1
10+:1

Users

"Data Pool"

Any GRB site

"Data pool" of full GOES (the complete level 1b data) would not be compressed, nor rebroadcast. Full GOES would be available for ground-based transfers & archive.

General GRB Assumptions

- User needs
    - All users and applications not known
    - Forecasting all future users and applications uncertain
    - If the data is available, user will work to gain access to it

- Users (DoD, WMO nations, academia, etc) will expect a similar (or higher) level of service

- Communications capabilities will continue to evolve – bringing improved capability, technologies, and lower cost

- Future data compression techniques will continue to improve (both lossless and lossy)

- Send out as much information (as opposed to just data) to as many users as possible while balancing cost of dissemination with the goal of maximizing the usefulness of the information

# How might we move from 100 to 24 Mbps for a rebroadcast?

- Data compression is the key
- Maintain a "**data pool**" concept for land access and archive of uncompressed sensor data
  - ➢ Users could then "test what is not being sent" for their own application(s)

- One method going from **~100 Mbps to 24 Mbps:**
  - ➢ 10X for the 0.5 km visible band
  - ➢ 6X for the "1km" bands
  - ➢ 2X for the IR bands of the ABI
  - ➢ 6X for the HES-IR

- Means approximately half of the band width would be used by the imager and half by the sounder; each image could be sent out

0.5 km visible data dominates the data rate of ABI

ABI Data Rates (Uncompressed)
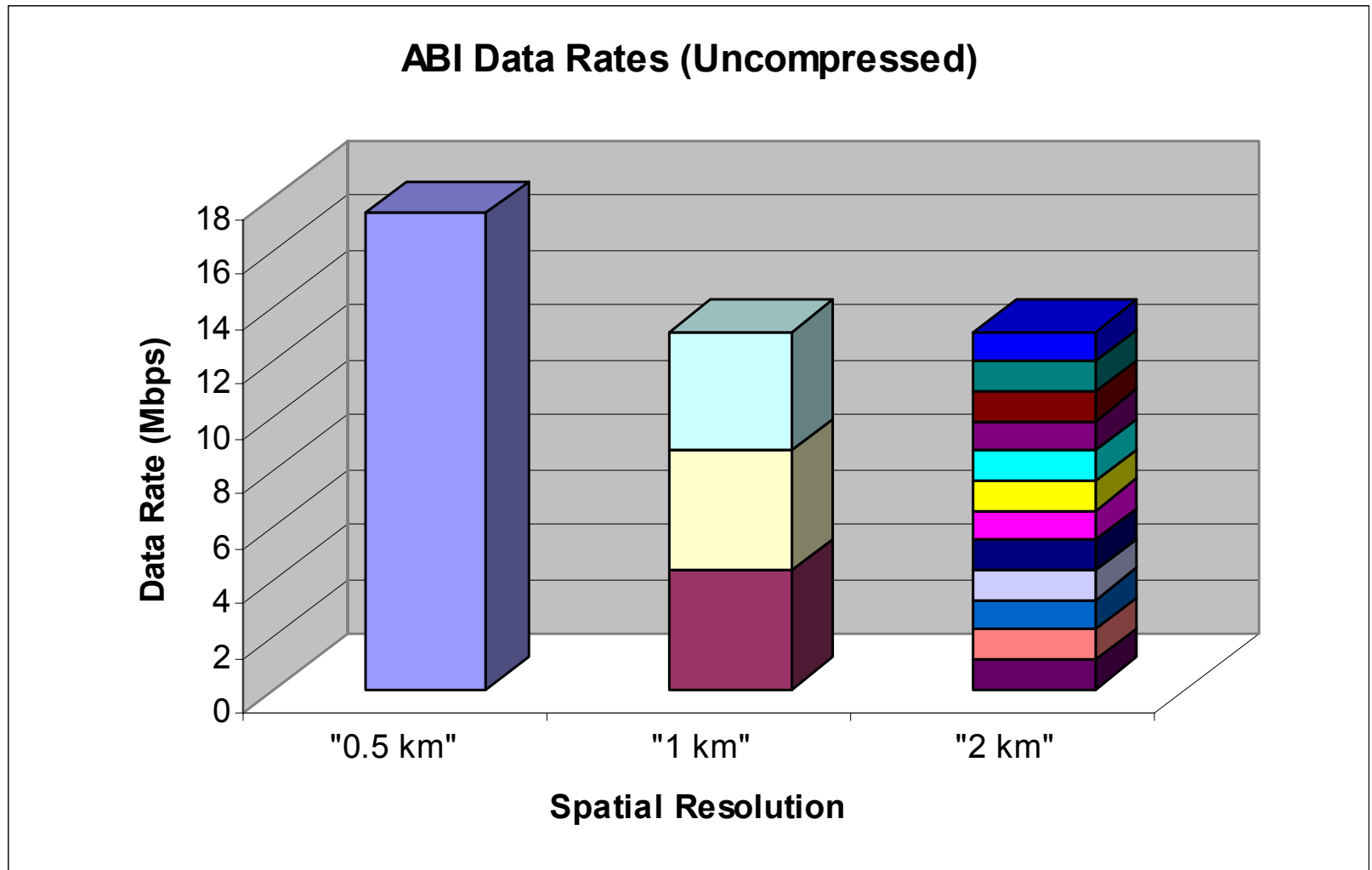
Total (uncompressed) 43.5 Mbps
Assuming 13-bit data and a 5-minute full disk scan mode

IR dominates the data rate of ABI after compression

ABI Data Rates (Compressed)
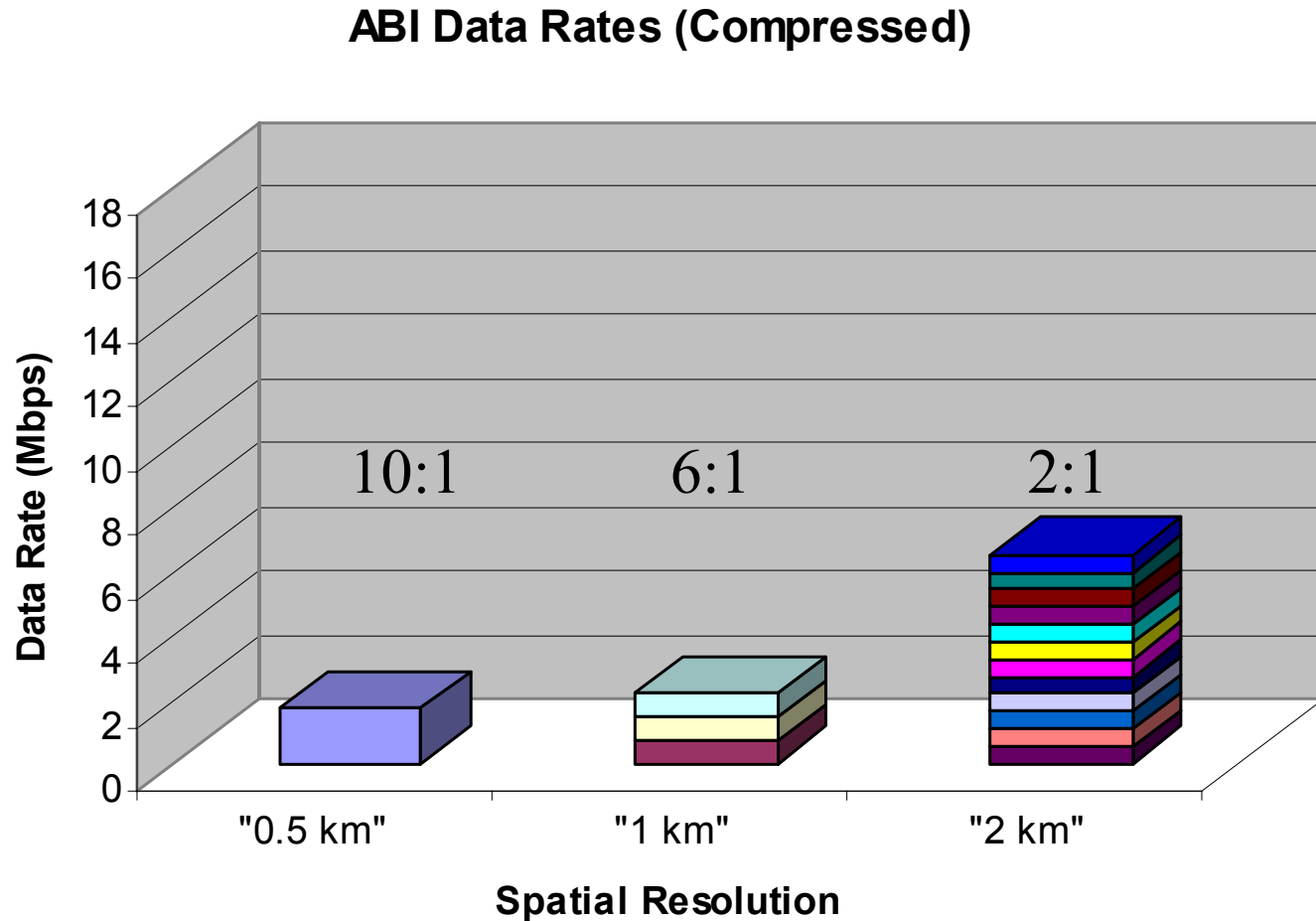
Total (uncompressed) 43.5 Mbps
Total (compressed)   10.4 Mbps

Ultraspectral sounder data for compression studies

AIRS: 2378 infrared channels, 135 scan lines x 90 cross-track footprints per granule

|			
Granule 9	00:53:31 UTC	-12 H	(Pacific Ocean, Daytime)
Granule 16	01:35:31 UTC	+2 H	(Europe, Nighttime)
Granule 60	05:59:31 UTC	+7 H	(Asia, Daytime)
Granule 82	08:11:31 UTC	-5 H	(North America, Nighttime)
Granule 120	11:59:31 UTC	-10 H	(Antarctica, Nighttime)
Granule 126	12:35:31 UTC	-0 H	(Africa, Daytime)
Granule 129	12:53:31 UTC	-2 H	(Arctic, Daytime)
Granule 151	15:05:31 UTC	+11 H	(Australia, Nighttime)
Granule 182	18:11:31 UTC	+8 H	(Asia, Nighttime)
Granule 193	19:17:31 UTC	-7 H	(North America, Daytime)

AIRS radiance field at wavenumber 900.3cm^{-1} for the 10 selected granules
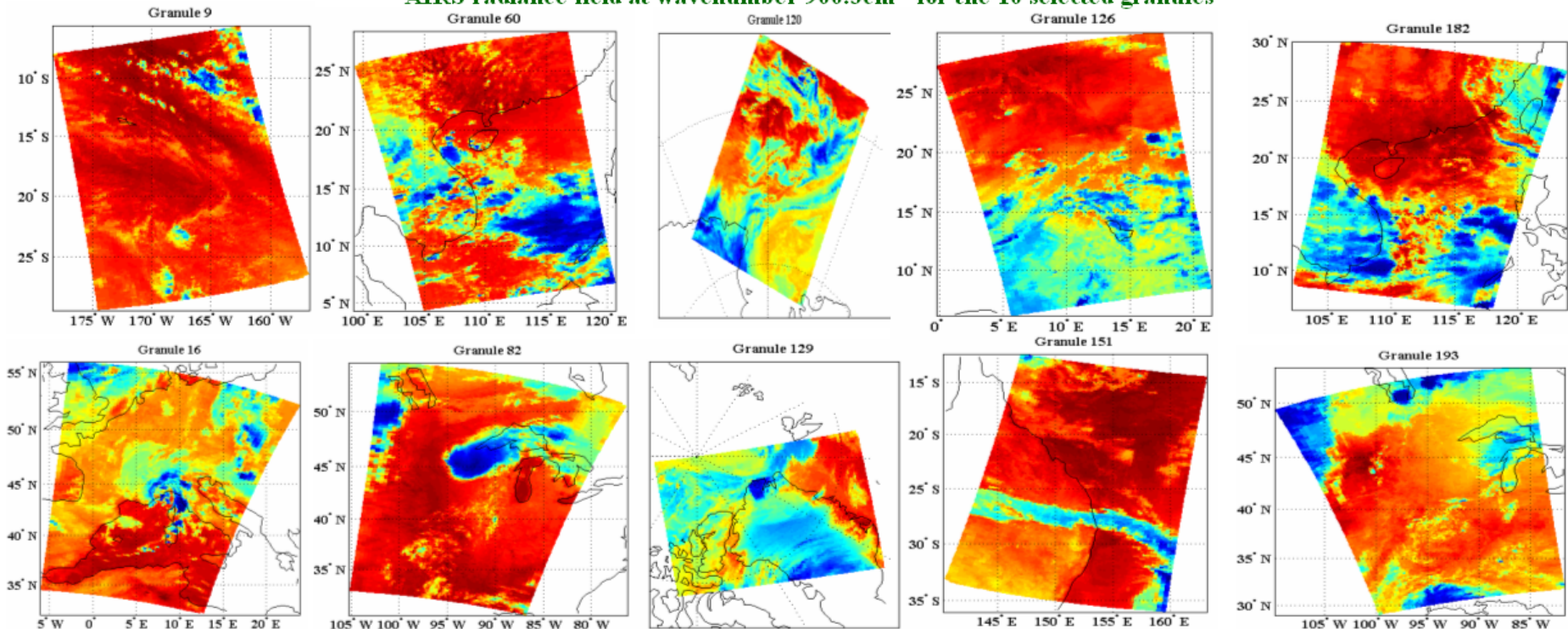
CIMSS's New Compression Scheme:
PPVQ (Predictive Partitioned Vector Quantization)

- ➤
- ➤
- ➤
- ➤

Granule 9

Granule 16

Compression Ratios on AIRS Digital Counts

| Granule	JPEG2000	PPVQ
9	2.378	3.352
16	2.440	3.360
60	2.294	3.303
82	2.525	3.385
120	2.401	3.308
126	2.291	3.293
129	2.518	3.376
151	2.335	3.259
182	2.251	3.224
193	2.302	3.272
Average	**2.374**	**3.313**
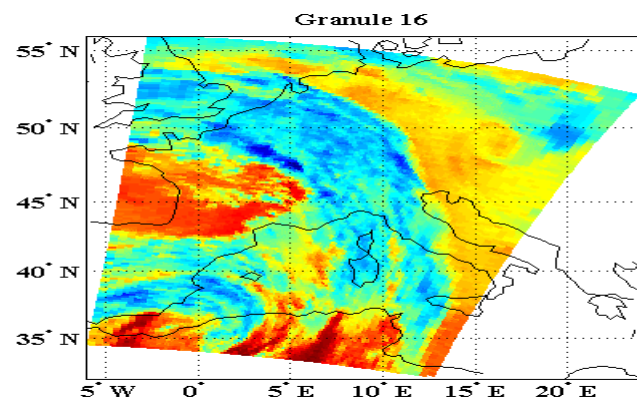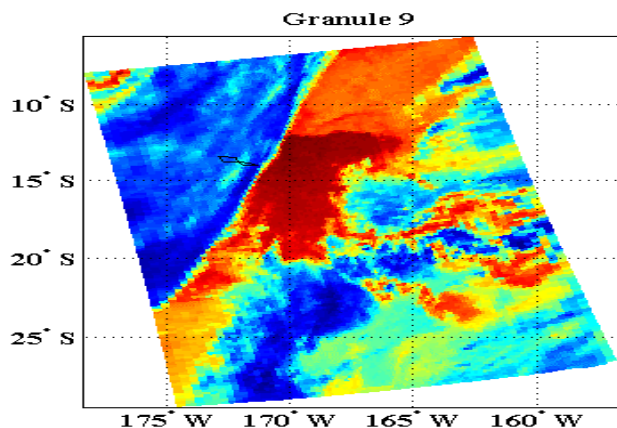
PPVQ outperforms JPEG2000 by 39% on average!
(3.313/2.374 = 1.39)

Summary -- ABI

ABI addresses Imager concerns by:
- increasing spatial resolution
    - closer to NWS goal of 0.5 km IR
- scanning faster
    - temporal sampling improved
    - more regions scanned
- adding bands
    - new and/or improved products enabled
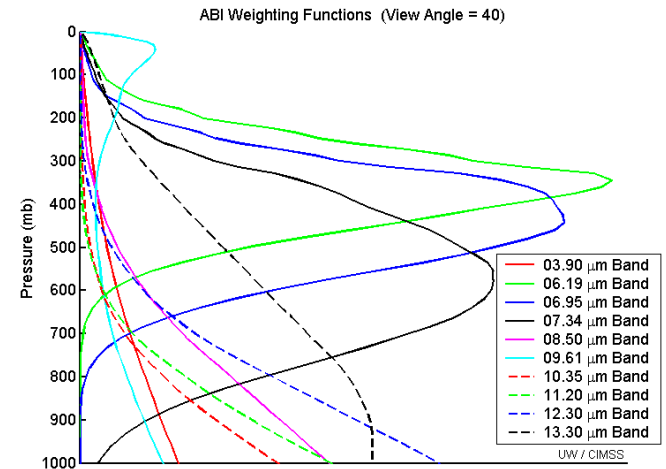
Simulations (from MODIS, AIRS, NAST-I, MSG and AVIRIS) show that the ABI addresses needs for cloud, moisture, air quality and surface products.

Every product from the current GOES imager will be improved! Every band on the ABI will be used for a number of products.

ABI will allow exciting new products from geostationary orbit, especially when combined with data from the HES.

GOES-R

The **great amount of information** from the GOES-R series will both offer a **continuation of current product and services**, but also allow for **improved or new capabilities**.

These products, based on validated requirements, will cover a wide range of phenomena. This includes applications relating to: weather, ocean, coastal zones, land, hazards, solar and space.

The Advanced Baseline Imager (ABI), the Hyperspectral Environmental Suite (HES), the Geostationary Lightning Mapper (GLM), the space and solar instrument suites (Solar Imaging Suite (SIS) and the Space Environment In-Situ Suite (SEISS) on GOES-R will enable much improved monitoring compared to current capabilities.

More information

ABI Research Home page (with a link to all these links):
- http://cimss.ssec.wisc.edu/goes/abi/

HES Research Home page:
- http://cimss.ssec.wisc.edu/goes/hes

GOES and MODIS Galleries:
- http://cimss.ssec.wisc.edu/goes/misc/interesting_images.html
- http://terra.ssec.wisc.edu/~gumley/images.html

ABI Documentation from NASA:
- http://goes2.gsfc.nasa.gov/abihome.htm

ABI Simulated Spectral Response functions:
- ftp://ftp.ssec.wisc.edu/ABI/SRF

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